Contents

Tables

Figures

12

Pathogens

12.1 INTRODUCTION

This chapter focuses on a number of pathogen issues including bacteria and protozoan occurrences. The topics, scope, and treatment plants selected for review were determined through a joint series of discussions between California Department of Water Resources (DWR) and the California Department of Health Services (DHS). Instead of incorporating a pathogen component into every watershed chapter, selected pathogen topics are highlighted using several water treatment plants (WTPs) from representative sections of the State Water Project (SWP) as examples of pathogen water quality. This chapter focuses solely on pathogen data. Potential contaminating activities that could contribute to pathogen contamination are discussed in individual watershed chapters. Additionally, the reader should refer to Chapter 2 for an in-depth discussion of drinking water regulations.

Representative sections of the SWP chosen for closer examination are presented in Table 12-1. Pumping facilities are discussed in Chapter 7 for the Southern California reservoirs, Chapter 5 for the South Bay Aqueduct (SBA), and Chapter 3 for the North Bay Aqueduct (NBA). Unless otherwise noted, all data in this chapter reflect only SWP raw water influent. In addition to raw water influent at selected WTPs, the majority of pathogen data collected by DWR was also examined in this section.

This chapter is divided into 2 parts. In the 1st part, pathogen water quality data is examined for the WTPs treating water from the selected sections of the SWP. Based on discussions with DHS, the following topics are covered in the 1st part:

- Bacteria Summary Statistics, Section 12.2
- Southern CA Reservoirs-Castaic, Silverwood
- SBA
- NBA
- DWR sample sites
- *Giardia* Cyst Removal, Section 12.3
- Recommended removal based on total coliform numbers
- Recommended removal based on *Giardia* numbers

Table 12-1 Geographical Areas of the SWP Examined for Pathogen Trends

Geographical Area	Agency	Water Treatment Plant
Southern California Reservoirs	MWDSC[a]	Jensen (Castaic Lake) Mills (Silverwood Lake)
South Bay Aqueduct	SCVWD[b] ACFCWCD Zone 7[c] ACWD[d]	Penitencia Del Valle Patterson Pass Water Treatment Plant 2
North Bay Aqueduct	City of Napa City of Benicia North Bay Regional City of Vallejo	Jameson Canyon Benicia NBR[e] Travis

[a] Metropolitan Water District of Southern California
[b] Santa Clara Valley Water District
[c] Alameda County Flood Control and Water Conservation District, Zone 7
[d] Alameda County Water District
[e] North Bay Regional

- *Cryptosporidium* Running Averages, Section 12.4
- Long Term 2 Enhanced Surface Water Treatment Rule (ESWTR) Microbial Index, Section 12.5

The 2nd part of this chapter summarizes work conducted by Dr. Michael Anderson of UC Riverside. In his paper, Dr. Anderson evaluates the impacts of body-contact recreation on water quality at SWP's 4 Southern California reservoirs: Perris, Castaic, Silverwood, and Pyramid. Appendix A contains the full text of Dr. Anderson's report.

Previous chapters suggest pathogen studies for several watersheds. During the years covered by this sanitary survey, the United States Environmental Protection Agency (EPA) promulgated 2 methods to examine *Cryptosporidium* and *Giardia* concentrations. They are the EPA's Information Collection Rule (ICR) and Method 1623. Municipal Water Quality Investigations (MWQI) at DWR has conducted special studies on both of these methods. Section 12.7, Protozoan Sampling Method Concerns, summarizes the issues surrounding the difficulty using these methods for pathogen sampling. The weakness in data quality using these methods and the inherent difficulty interpreting the results, make conducting some of the proposed pathogen studies in previous watershed chapters problematic. Appendices B and C contain details of the sample design and data analyses conducted by DWR using either the ICR method (Appendix B) or Method 1623 (Appendix C).

12.2 BACTERIA SUMMARY

Table 12-2 summarizes total coliform data for all sites routinely sampled by DWR and selected WTPs, which processed only SWP water (or virtually only SWP water as in the case of the Jensen and Mills Filtration Plants (FPs)). In the case of SBA contractors, data from the SBA and Lake Del Valle were combined. Tables 12-3 and 12-4 summarize fecal coliform and *E. coli* data, respectively. Data are not always directly comparable. Different WTPs often sampled on different days or used different sampling regimes. In some cases, data were not available for the entire period of record; in others, sampling frequency varied between those collected weekly and those collected daily. Table 12-2 also illustrates the effect of dilution and test sensitivity on calculated densities. In some cases, the maximum values could only be listed as greater than a calculated value (for example, not enough dilutions were conducted to resolve densities beyond the stated maximum value). In other cases, the sensitivity of the test could not resolve densities below a certain level, for example, less than 2. For statistical calculations, the maximum value was substituted for values greater than the stated maximum level. Zero was substitued for values reported as less than the detection limit. In both cases, this could potentially skew the results; however, it was felt that this approach was preferable to removing the data completely from the analysis. While data may not have been always directly comparable, the size of most datasets provided patterns of occurrence that should be fairly robust.

Currently, DHS only requires presence/absence reporting for *E. coli*; however, all plants profiled enumerated *E. coli*. Of particular importance was the use of Colilert™ data for the measurement of both total and *E. coli*. The majority of utilities profiled used either Multiple Tube Fermentation (MTF) or Membrane Filtration (MF) to enumerate total coliforms in their source water. However, a significant minority used the enzyme-based Colilert™ method. A number of comparative tests have found no significant difference between Colilert™ results and either the MTF or MF methods (Covert and others 1988, Wollin and others 1992). Others have found a slight, nonsignificant bias toward Colilert ™ (Edberg and others 1988, Katamay 1990). However, Smith (1992) found a high rate of false positives for total coliform using California Aqueduct water and the Colilert™ method. Eighty-two percent of tests that were negative for total coliform using the MTF method were recorded as positive for total coliform by the Colilert™ method and were found to be non-coliforms upon subculturing. A more recent study has found a lower rate of false positives for total coliform with Colilert™ (between 13% and 36%), but high rates of false positives for total coliform with other enzyme-based methods, for example, Colilert 18™ or E*Colite™ (Smith 1999). Unfortunately, no replication appeared to have been conducted with the 1999 study, but these results suggest that the most conservative approach to determining source water occurrence of total coliform would be to exclude Colilert™ data. In the case of contractors along the SBA, 3 of the 4 utilities used Colilert™ for at least 3 of the 4 years covered by this sanitary survey update. Because only 1 SBA WTP would have been examined if Colilert™ data had been excluded, DHS and DWR decided to include Colilert™ data for SBA contractors. With respect to *E. coli*, Smith found the methods are comparable (1992, 1999); therefore, all Colilert™ *E. coli* data were included.

Table 12-2 Total Coliform Values for Sites Sampled by DWR and Selected Water Treatment Plants Receiving Only SWP Water

(Except Where Noted, All Samples Analyzed by Multiple Tube Fermentation) (MPN/100 mL)

Agency	Location	Median	Min	Max	Percentile Range (10-90%)	# Detects/ Total Sampled
DWR	Barker Slough Pumping Plant[a]	500	4	50,000	157 – 1,600	34/34
	Banks Pumping Plant[b]	50	7	3,000	15 - 710	24/24
	Delta Mendota Canal @ McCabe Road[b]	75	8	9,000	16 - 780	24/24
	Arroyo Valle Creek Inflow to Lake Del Valle[c]	110	13	3,000	38 - 760	15/15
MWDSC	Jensen Filtration Plant[d]	4	<2	≥1,600	<2 - 50	NA/1,040
	Mills Filtration Plant[d]	4	<2	≥1,600	<2 - 17	NA/1,011
NBA	City of Benicia WTP[e]	105	9	≥1,600	30 - 300	184/184
	Jameson Canyon WTP (Napa)[f]	170	8	>2,400	19 – 1,600	54/54
	North Bay Regional WTP (Fairfield, Vacaville)[g]	100 CFU/ 100 mLs[l]	<4	5,500	20 - 300	504/517
	Travis Air Force Base WTP (Vallejo)[h]	50 CFU/ 100 mLs[l]	<4	3,300	10 - 200	199/206
SBA	Penitencia WTP[i]	22	< 2	1,600	4-80	242/251
	Del Valle WTP[j**]	201	0	1,652	18 – >1,003	204/206
	Patterson Pass WTP[h**]	59	0	>1,003	6 - 583	200/203
	WTP2[k*]	500	<2	≥1,600	50 –1,600	993/995

[a] Samples collected monthly from Nov 1996 to Dec 1999, monthly sampling to continue indefinitely.
[b] Samples collected monthly from Apr 1996 to May 1998, no samples collected since May 1998.
[c] Sampled monthly from Apr 1996 to May 1998 unless no flow.
[d] Samples collected 4 times a week from Jan 1996 to Jun 2000.
[e] Samples collected Jan 1996 and then weekly from Mar 1996 to Dec 1999.
[f] Samples collected weekly from May 1997 to Dec 1999 when plant receiving NBA water, otherwise off-line.
[g] Samples collected daily from Mar 1996 to Jan 1998 when plant receiving NBA water. Plant switched to Colilert™ method Feb 1998. Colilert™ data not used for calculations.
[h] Samples collected weekly from Jan 1996 to Dec 1999.
[i] Samples collected daily from Jan 1996 to Apr 1997. Samples collected weekly May 1997 to Dec 1999.
[j] Samples generally collected weekly from Jan 1996 to Dec 1999. No data provided from 16 Jan to 13 Feb 1996.
[k] Sample collected Jan 1996 and then generally daily from Oct 1996 to Dec 1999. No data provided from 23 Oct 1996 to 26 Jan 1998, 2 Nov to 17 Nov 1998, 25 Oct to 26 Nov 1999.
[l] Samples analyzed by Membrane Filtration.
* Samples analyzed by Colilert™.
** Beginning Feb 1997, samples analyzed by Colilert™.

Summary Statistics calculated by substituting 0 for all values less than the detection limit.
Recorded value substituted for values recorded as > than the recorded value.
NA-- unable to analyze from data received

Table 12-3 Fecal Coliform Values for Sites Sampled by DWR and Selected Water Treatment Plants Receiving Only SWP Water

(Except Where Noted, All Samples Analyzed by Multiple Tube Fermentation) (MPN/100 mL)

Agency	Location	Median	Min	Max	Percentile Range (10-90%)	Number Detects/ Total Sampled
DWR	Barker Slough Pumping Plant[a]	220	2	3,000	75 - 500	36/36
	Banks Pumping Plant[b]	14	4	300	7 - 290	26/26
	Delta Mendota Canal @ McCabe Road[b]	29	<2	240	6 - 105	24/26
	Arroyo Valle Creek Inflow to Lake Del Valle[c]	70	2	800	23 - 200	15/15
MWDSC	Jensen Filtration Plant[d]	2	<2	≥1600	<2 - 30	NA/1,040
	Mills Filtration Plant[d]	<2	<2	900	< 2 - 4	NA/1,016
NBA	City of Benicia WTP	not analyzed				
	Jameson Canyon WTP (Napa)	not analyzed				
	North Bay Regional WTP (Fairfield, Vacaville)	not analyzed				
	Travis Air Force Base WTP (Vallejo)[e]	20 CFU/ 100 mL[h]	<2	3,300	< 2 - 132	168/203
SBA	Penitencia WTP[f]	7	<2	240	< 2 - 30	211/251
	Del Valle WTP[g]	-	-	-	-	-
	Patterson Pass WTP[g]	-	-	-	-	-
	WTP2	NA				

[a] Samples collected monthly from Nov 1996 to Dec 1999, monthly sampling to continue indefinitely.
[b] Samples collected monthly from Apr 1996 to May 1998, no samples collected since May 1998.
[c] Samples collected monthly from Apr 1996 to May 1998 unless no flow.
[d] Samples collected 4 times a week from Jan 1996 to Jun 2000.
[e] Samples collected weekly from Jan 1996 to Dec 1999.
[f] Samples collected daily from Jan 1996 to Apr 1997. Samples collected weekly from May 1997 to Dec 1999.
[g] Fecal coliform samples only collected Jan 1997.
[h] Samples analyzed by Membrane Filtration.
NA—not analyzed.
Summary Statistics calculated by substituting 0 for all values less than the detection limit.
Recorded value substituted for values recorded as > than the recorded value.

Table 12-4 *E. coli* Values for Sites Sampled by DWR and Selected Water Treatment Plants Receiving Only SWP Water (Except Where Noted, All Samples Analyzed by Multiple Tube Fermentation) (MPN/100 mL)

Agency	Location	Median	Min	Max	Percentile Range (10-90%)	Number Detects/ Total Sampled
DWR	Barker Slough Pumping Plant[a]	195	<2	3,000	60 - 500	35/36
	Banks Pumping Plant	NA				
	Delta Mendota Canal @ McCabe Road	NA				
	Arroyo Valle Creek Inflow to Lake Del Valle	NA				
MWDSC	Jensen Filtration Plant[b]	2	<2	≥1,600	<2 - 30	NA/1,040
	Mills Filtration Plant[b]	<2	<2	900	<2 - 4	NA/1,016
NBA	City of Benicia WTP[c]	26	<2	>1,600	6 - 94	181/183
	Jameson Canyon WTP (Napa)[d]	17	<2	>2,400	4 - 687	26/27
	North Bay Regional WTP (Fairfield, Vacaville)	not reported				
	Travis Air Force Base WTP (Vallejo)	NA				
SBA	Penitencia WTP[e]	4	<2	240	< 2 - 23	207/251
	Del Valle WTP[f*]	5	0	109	0 – 29	86/102
	Patterson Pass WTP[f*]	1	0	101	0 – 26	72/100
	WTP2[g*]	7	<2	>1,600	<2 - 33	871/995

[a] Samples collected monthly Nov 1996 to Dec 1999, monthly sampling to continue indefinitely
[b] Samples collected 4 times a week from Jan 1996 to Jun 2000.
[c] Sample collected Jan 1996 and then weekly from Mar 1996 to Dec 1999.
[d] Samples collected weekly Nov 1998 to Dec 1999 when plant receiving NBA water, otherwise off-line.
[e] Samples collected daily, Jan 1996 to Apr 1997. Samples collected weekly in May 1997 to Dec 1999.
[f] Samples collected from Feb 1997 to Dec 1998. Sampling discontinued per ELAP approval.
[g] Sample collected Jan 1996 and then generally daily from Oct 1996 to Dec 1999. No data provided from 23 Oct 1996 to 26 Nov 1998, 2 Nov 1998 to 17 Nov 1998, 25 Oct 1999 to 26 Nov 1999.
[*] Samples analyzed by Colilert™
NA—not analyzed
Summary Statistics calculated by substituting 0 for all values less than the detection limit
Recorded value substituted for values recorded as > than the recorded value.

12.2.1 BACTERIA SUMMARY STATISTICS – SOUTHERN CALIFORNIA RESERVOIRS

At 4 most probable number (MPN)/100 mL, the median total coliform densities were identical for the Jensen and Mills FPs of Metropolitan Water District of Southern California (MWDSC) (Table 12-2). Total coliform are measured 4 days a week at each of these plants, so these results are highly robust. Furthermore, although samples greater than or equal to 1600 MPN/100 mL were detected at both sites, 90% of all total coliform densities fell below 50 and 17 MPN/100 mL for Jensen and Mills, respectively.

Like total coliforms, fecal coliform detected at MWDSC's Jensen and Mills FPs were also very low and were nearly identical (2 and <2 MPN/100 mL for Jensen and Mills, respectively) (Table 12-3). At both plants, values near or above 1,000 MPN/100 mL have been detected; however, 90% of all detections fell below 30 or 4 MPN/100 mL for Jensen and Mills, respectively.

Median , minimum, maximum, and percentile ranges for *E. coli* at the Jensen and Mills FPs were identical to their respective fecal coliform values (Table 12-4).

12.2.2 BACTERIA SUMMARY STATISTICS – SOUTH BAY AQUEDUCT

The highest total coliform densities of any of the WTPs examined were calculated from Water Treatment Plant 2 (WTP2) of the Alameda County Water District (ACWD). WTP2 only receives water from the SBA and, like Jensen and Mills, analyzes total coliform daily. The plant's 4-year median of 500 MPN/100 mL was 2 orders of magnitude higher than the 4 MPN/100 mL total coliform median calculated for the MWDSC plants (Table 12-2). However, WTP2 also uses Colilert™ to analyze total coliform; therefore, the inflation of total coliform numbers cannot be ruled out. Comparison of Jensen and Mills with the only SBA plant to use the MTF method (Penitencia WTP) showed similar percentile ranges and minimum and maximum values; however, median densities were higher at Penitencia than at the Southern California WTPs.

Of the 4 plants receiving SBA water, WTP2 had the highest median total coliform densities while Penitencia had the lowest. Although Penitencia's total coliform densities could reach as high as 1,600 MPN/100 mL or greater, its median and percentile ranges were the lowest of any of the SBA plants profiled. With respect to the 2 remaining SBA WTPs—Patterson Pass and Del Valle—the Patterson Pass WTP appeared to have better total coliform water quality. Like the Del Valle WTP, Patterson Pass WTP has detections of total coliform above 1,000 MPN/100 mL. However, Patterson Pass's percentile ranges and its 4-year median of 59 MPN/100 mL indicate that high total coliform densities have not occurred as frequently or in as high of numbers as at the Del Valle WTP.

With the exception of the Patterson Pass WTP, all the SBA treatment plants examined received their water from the enclosed sections of the SBA. It is not known why such a large difference in total coliform numbers should be observed between the Penitencia WTP and the Del Valle WTP and WTP2. One explanation may be the method used to analyze for total coliform. Both WTP2 and the Del Valle WTP use Colilert™ to analyze their source waters. The Penitencia WTP uses the MTF method. The higher bacterial concentrations at WTP2 and the Del Valle WTP could be explained if Colilert™ detects bacteria other than coliforms. The Patterson Pass WTP also analyzes total coliform using the Colilert™ method. This is the only WTP examined that received water from the Delta. Furthermore, the 30 million gallons per day (mgd) raw water reservoir at the plant serves as a presedimentation basin, which appears to improve the water quality for several constituents including bacteria (Deol pers. comm.).

Unfortunately, only 1 (Penitencia WTP) out of 4 SBA plants monitors for fecal coliform, thus the data could not be used as an indicator of bacterial water quality among SBA WTPs (Table 12-3). All 4 plants monitor for *E. coli.* The data indicated that although WTP2's total coliform levels were substantially higher than any of the other SBA plants profiled, this was not the case for the plant's *E. coli* measurements (Table 12-4). *E. coli* numbers at WTP2 could reach higher levels than *E. coli* numbers detected at Penitencia, Del Valle, and Patterson Pass WTPs (>1600 MPN/100 mL vs. 240 MPN/100 mL, 109 MPN/100mL, and 101 MPN/100 mL, respectively). However, the percentile ranges and the medians between the 4 plants were similar, suggesting that *E. coli* levels at WTP2 are only slightly higher than at the other SBA plants profiled.

When compared to other daily measurements of *E. coli*, WTP2's appeared similar to daily samples collected from the Jensen FP in Southern California. However, the median suggested that higher *E. coli* densities occurred more frequently at WTP2.

12.2.3 BACTERIA SUMMARY STATISTICS – NORTH BAY AQUEDUCT

Unlike the SBA WTPs where some plants had relatively low median coliform values and others had relatively high values, the median values for all of the NBA WTPs profiled were relatively high (Table 12-2). In some cases NBA data sets did not cover a full year of sampling or the entire 4-year reporting period (Jameson Canyon and North Bay Regional WTP). With this sort of data, it is important to remember that samples collected for only a part of the year may create summary statistics skewed to the water quality conditions associated with the season of collection. For example, on average plants that primarily operate in the winter would be expected to have higher pathogen densities than plants that operate all year. Of the NBA plants profiled, the City of Napa's Jameson Canyon WTP uses NBA water most often in the winter.

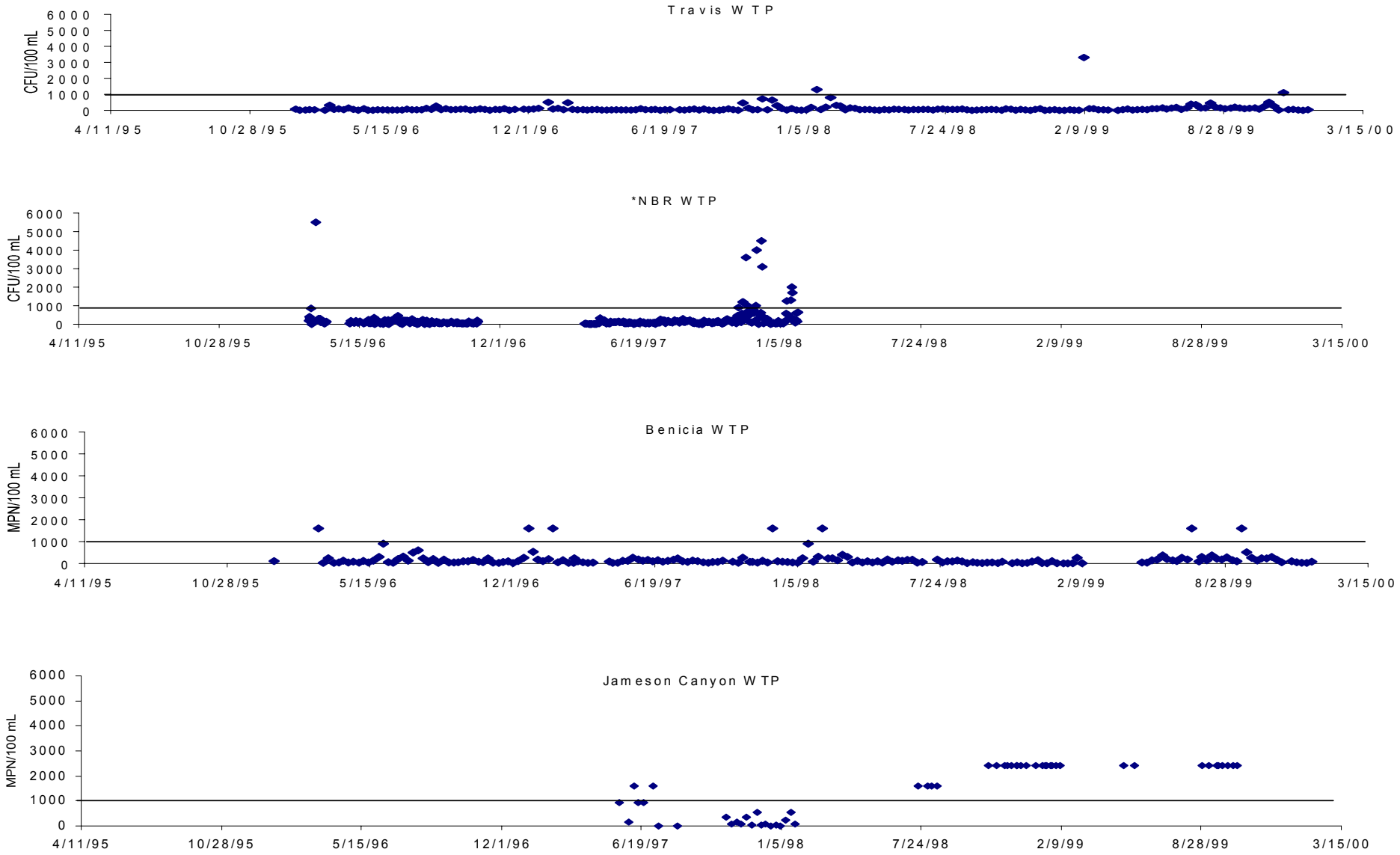
Of the NBA plants, the highest reported total coliform values occurred at the North Bay Regional (NBR) and the Jameson Canyon WTPs. However, 90% of NBR WTP's coliform densities fell at or below 300 Colony Forming Units (CFU)/100 mL, whereas 90% of Jameson Canyon's total colform densities fell at or below 1600 MPN/100 mL. The NBR WTP used MF during this period to enumerate total coliform while the Jameson Canyon WTP used the MTF method. When evaluating raw water using median values, DHS considers the MTF and the MF methods equivalent (Mills pers. comm.), and both labs must show adequate correlation between MTF and MF in order to be certified to use the MF

method. However, Standard Methods does note that results from the MTF test would be expected to be higher than MF results because of a built-in positive statistical bias of approximately 23%, but that 80% of MF test results would be expected to fall within the 95% confidence limits of the MTF test results (Anonymous 1995)

The NBR WTP has the option of switching to an alternative water source; however, during the period when this plant was using NBA water, its summary statistics were also similar to the Benicia and Travis WTPs (Table 12-2). The NBR used MF from January 1996 through January 1998. In February 1998, the laboratory began using Colilert™. Total coliform analyzed by Colilert™ were not included in the analysis. The WTPs for the City of Benicia and Travis AFB rely primarily on NBA water all year. Both plants analyze their raw water weekly for total coliform. Although the City of Benicia measures total coliform using MTF and Travis uses MF, the results between the 2 plants were similar.

As noted previously, Jameson Canyon's statistics may be skewed toward higher numbers; however, an analysis of the data suggests that the higher total coliform numbers may reflect more than a seasonal inflation of the numbers or the effects of a small sample size. Both the Jameson Canyon and the City of Benicia's WTPs rely principally on NBA water. Both also use the MTF method to evaluate total coliforms. Upstream to the Cordelia Forebay, the same conveyance structure is used by both utilities. Downstream of the Cordelia Forebay, separate conveyance structures deliver water to the respective plants. An analysis of the 39 total coliform samples collected at the 2 plants within 24 hours of each other found that nearly half (18/39) of Jameson Canyon's total coliform 95% confidence intervals (CI) did not overlap with total coliform 95% CI values from the Benicia WTP (Figure 12-1). Because contamination would have to occur downstream of the Cordelia Forebay, there may be an unknown source of total coliform contamination between the Cordelia Forebay and the inlet to the Jameson Canyon WTP. To corroborate this conclusion, total coliform densities were also examined upstream of the Cordelia Forebay. Because NBR uses Colilert™, total coliform patterns could not be examined at the NBR WTP upstream of the Cordelia Forebay. However, the Travis AFB WTP is also upstream of Jameson Canyon and the Cordelia Forebay. Total coliform at this plant is analyzed by MF. As shown in Figure 12-1, periods of high total coliform values at the Jameson Canyon WTP were not observed at the Travis AFB WTP. With respect to total coliform, a 2nd pattern was observed in winter 1997/1998 at the NBR WTP. When compared to the Travis AFB WTP, total coliform values from November 1997 through January 1998 were higher at the NBR WTP (MF method was used by the NBR plant during this period). However, statistical comparisons of total coliform densities collected on the same day ($n = 12$) found no significant difference ($p = 0.53$), and the patterns between the 2 plants were similar (Spearman $r = 0.72$). One factor in these results may have been the small sample size.

Figure 12-1 Total Coliform Densities (CFU or MPN/100 mL) for Selected NBA Utilities



0 substituted for values < DL. Values > upper DL changed to upper value.

*NBR began use of Colilert 2/98

Fecal coliform values were only available from the Travis WTP (Table 12-3). Samples are collected weekly. Fecal coliform values as high as 3,300 CFU/100 mL were recorded at this plant. Ninety percent of this plant's fecal coliform values fell below 132 CFU/mL, whereas for other plants profiled, 90% of their fecal coliform fell below 40 MPN/100 mL.

E. coli values from NBA contractors were also higher than *E. coli* values recorded from the other plants profiled in this section. For example, both the City of Benicia and the ACWD's WTP2 could experience *E. coli* numbers above 1,600 MPN/100 mL (Table 12-4). However, Benicia's *E. coli* values were higher than WTP2's both statistically (Mann-Whitney, 2-tailed, $p < 0.05$) and visually (median and percentile ranges). Median *E. coli* values at Jameson Canyon were similar to those observed at Benicia; however, as shown by the maximum and percentile range values, *E. coli* contamination at Jameson Canyon could be more severe than at the Benicia WTP.

In summary, bacterial statistics and conclusions in this chapter were derived from very large datasets. Bacteriological sampling at the utilities generally occurred weekly or, in the case of the MWDSC data, 4 times a week. Therefore, this data suggest fairly robust occurrence patterns. However, based on method differences, direct comparisons were not always possible. Given these caveats, bacteriological statistics suggested that MWDSC generally had the best bacteriological water quality of any of the SWP utilities examined. This does not mean that the MWDSC plants could not experience episodic events where bacteria numbers peaked (for example, during rainfall events and as shown by the maximum values recorded). Based on 90th percentile values, 90% of MWDSC's total, fecal, or *E. coli* values fell below 50 MPN/100 mL. This suggests that any proactive measures to minimize livestock and recreation impacts should continue. The same conclusion appeared to be true for fecal and *E. coli* contamination in the SBA. Ninety percent of SBA utilities' fecal and *E. coli* densities also fell below 50 MPN/100 mL. Like the Southern California reservoirs, this suggested that any proactive measures to minimize the impacts of livestock and recreation should be continued. It is difficult to determine the true density of total coliform numbers for most SBA utilities because of the potential confounding factor associated with the Colilert ™ method; however, 90% of the total coliform densities from the 1 utility that did not use Colilert ™ (SCVWD) were below 80 MPN/100 mL. In some cases NBA bacteria data could be more problematic to interpret, but with respect to fecal and *E. coli* values, NBA contractors appeared to experience the worst bacteriological water quality of any of the plants examined. Data suggested *E. coli* contamination occurring between the Cordelia Forebay and the Jameson Canyon WTP. The uncovered Napa Turnout tank is the 1st obvious source to examine for contamination. For all NBA contractors, their higher levels of bacterial contamination probably reflect the influence of easy access to the slough by livestock.

12.2.4 BACTERIA SUMMARY – DWR

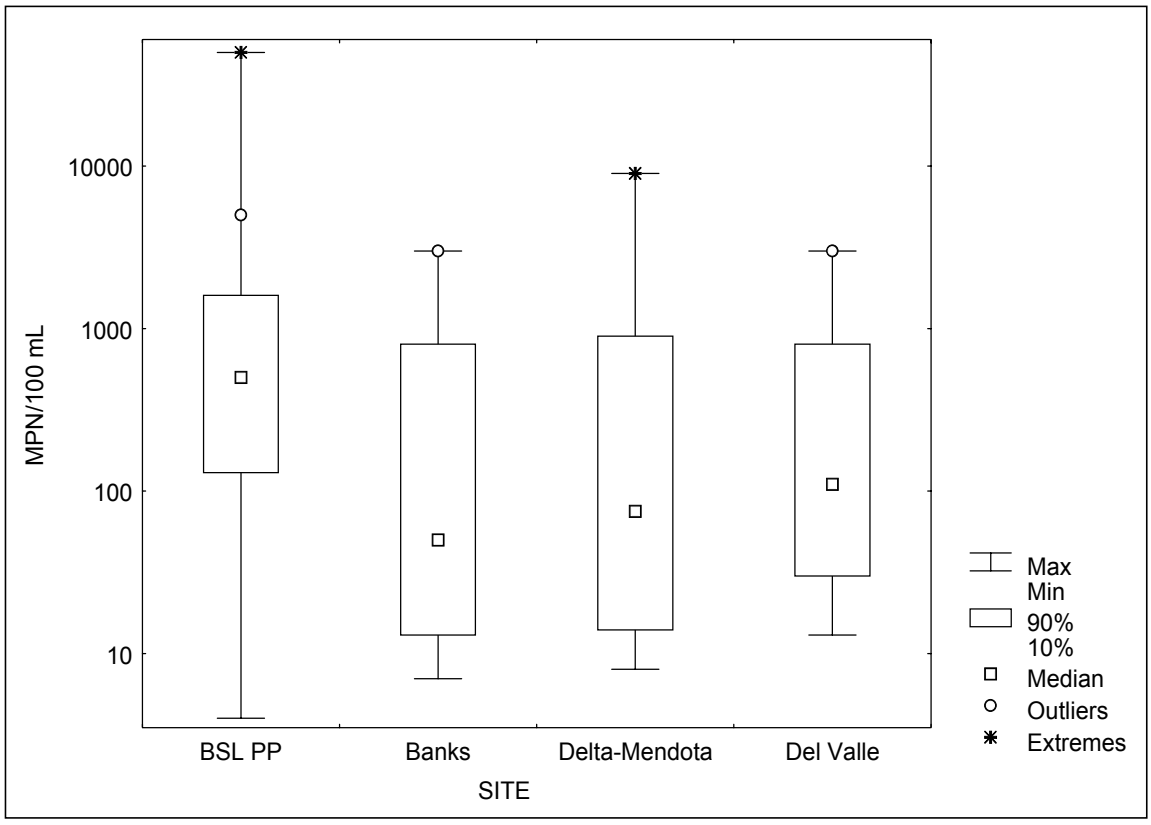
Tables 12-2 through 12-4 summarize all total, fecal coliform and *E. coli* sampling of the SWP between 1996 and 1999 conducted by DWR's Division of Operation and Maintenance (O&M). Bacteria data were also collected in the summers of 1996 and 1997 at the O'Neill Forebay. However, the data were only recorded as presence/absence; therefore, no quantification was possible. See Chapter 8, Section 2.4.2 for this information. Not shown are the few occasional samples that have been collected by O&M on the SWP or the nonelectronic data collected at the 5 small WTPs serving O&M's district offices.

Of the 4 sites sampled, coliform data for the Barker Slough Pumping Plant are the most complete. Total and fecal coliform and *E. coli* data have been collected there monthly since November 1996. Monthly sampling has continued through 2001 and is slated to continue based on contractor input. Of the remaining 3 sites, monthly samples for total and fecal coliform were generally collected between April 1996 and May 1998 as part of the EPA's ICR sampling program at the Banks Pumping Plant, Delta-Mendota Canal at McCabe Road. At the inflow of Arroyo Valle Creek to Lake Del Valle, samples were collected during the rainy season (late October/November to May) or during storm events (October 1996 to May 1998). No *E. coli* data were available at these 3 sites.

Based on input from SBA contractors, O&M resumed bacteria (total, fecal and *E. coli*) sampling in Lake Del Valle beginning September 2000. Samples are collected monthly at the Conservation Outlet Works tunnel during Lake Del Valle releases. Additionally, samples are collected quarterly at the lake's surface and 2 valve locations—the 650-foot and 670-foot valve elevations. Sampling for these and other parameters is expected to continue for at least a year at which time data will be reviewed and determined if continued sampling is necessary (Janik pers. comm.).

Because of the small dataset and the infrequency of sampling (once a month), any comparisons or conclusions between the DWR sites can only be

Figure 12-2 Total Coliforms for Sites Sampled by DWR, 1996 to 1999



considered preliminary. Based on the size of the dataset, data from the Barker Slough Pumping Plant are the most robust. However, to verify the observations between the respective DWR sampling sites, a more rigorous sampling program overall would be required. With these caveats, of the 4 DWR sites sampled, the highest median total and fecal coliform values occurred at the Barker Slough Pumping Plant while the lowest values occurred at the Banks Pumping Plant. Median total and fecal coliform levels at the Barker Slough Pumping Plant (500 and 220 MPN/100 mL, respectively) were approximately an order of magnitude higher than median values at Banks Pumping Plant or the Delta-Mendota Canal (Tables 12-2 and 12-3, respectively). Also, the maximum recorded value at the Barker Slough Pumping Plant was 50,000 MPN/100 mL—the highest total coliform value of any site profiled in this section. Barker Slough Pumping Plant also showed the largest variation in bacterial density (Figure 12-2). Ninety percent of Barker Slough samples were found at 1,600 MPN/100 mL or less. In contrast, 90% of samples collected at the Arroyo Valle Creek site (the site with the next highest total coliform densities) fell at or below 760 MPN/100 mL. As stated earlier, samples were only collected at the Arroyo Valle site during the rainy season. Often the highest coliform densities are observed during the rainy season. This suggests that under conditions conducive to high coliform densities, coliform levels at the Arroyo Valle site were still lower than those observed at Barker Slough; however, the smaller sample size may also be a factor in these results. In general total, fecal, and *E. coli* medians and percentile ranges at the DWR sampling sites were higher than those observed at the WTPs; however, the differences in sampling frequencies or sample sizes precludes robust conclusions.

In addition to O&M, the Department's MWQI unit has collected bacteria data for special studies (Table 12-5). In general, over the 4-year period, less than 15 samples have been collected at any 1 site. The only exceptions are many locations within the Barker Slough sampling area and the Natomas East Main

Table 12-5 Coliform and *E. coli* Values in MPN/ 100 mL for all Samples Collected by MWQI, 1996 to 1999[a]

	Total coliform			*E. coli*					
	Colilert™			Colilert			EC-MUG		
Site	Median	Range	Detects/ total sampled	Median	Range	Detects/ total sampled	Median	Range	Detects/ total sampled
Alamar					22	1/1			
Alomar Marina				<1	<1	0/4			
Alomar Marina								<2	0/1
American				32	3 - 145	10/10			
Banks				30	3 - 238	8/8			
Barker Sl @ Cook Rd				262	18 – 3,240	50/50			
BarkerNoBay				113	11 – 1,013	30/30			
BarkerNoBay	<1	<1	0/11						
BkrSlDalRd					488	1/1			
BkrSlHayRd					1,733	1/1			
Calhoun Cut @ Hwy 1				238	29 – 2,419	51/51			
Camplbell					74	1/1			
ConCosPP1				12	4 - 41	10/10			
Dally				1,468	326 – 7,701	4/4			
DMC				25	9 - 782	11/11			
Fremont					48	1/1			
Greenes				6	< 2 - 50	8/12			
Greenes								<2	0/1
Greenes									
Greenes									
Hay				1,811	192 – 6,131	6/6			
Lindsey Sl. @ Bridge				18	2 - 782	50/50			
MallardIS				12	3 - 78	11/11			
Meridian					1,640	1/1			
MiddleR				13	3 - 364	10/10			
Miller					27	1/1			
Natomas EMDC A EL CA				345	52 – 12,033	25/25			
Natomas EMDC A EL CA	<1	<1	0/19						
OldRivBacISL				6	2 - 344	12/12			
PS-1/ Mokelumne					831	1/1			
SacWSacINT				10	6 - 21	9/9			
Shag				165	101 - 659	3/3			
SJRMossDale				109	7 - 406	10/10			
Station09				12	3 - 531	11/11			
Vernalis				70	< 2 – 3,440	11/15			
Vernalis								<2	0/1

[a] No bacteria samples in database prior to 1996.

Notes: Locations in bold are sites with *E. coli* numbers above 1,000 MPN.
Recorded values substituted for values recorded as > recorded value.
Summary statistics calculated by substituting 0 for values less than detection limit.

Drainage Canal at El Camino. Of the 35 sites sampled by MWQI, 9 had *E. coli* numbers with maximum values ≥ 1,000 MPN/100 mL. The majority of these samples were collected from the Barker Slough sampling area; however, the highest value (12,033 MPN/100 mL) was detected at the Natomas East Main Drainage Canal in an urban area

12.3 *GIARDIA*

12.3.1 RECOMMENDED REMOVAL BASED ON TOTAL COLIFORM

The Surface Water Treatment Rule sets minimum treatment requirements for source waters used in the State, which are of reasonably high quality. The EPA based the federal regulations on a health risk of 1 case of microbiologically caused illness per year per 10,000 people and provided guidance on levels of protection for sources with varying concentrations of *Giardia* cysts. However, in some situations source waters may be subjected to significant sewage and recreational hazards where it may be necessary to require higher levels of virus and cyst removal (DHS 1991). Additionally, monitoring for *Giardia* is not always reliable, and for smaller utilities, it may not be economically feasible. To determine the minimum levels of treatment required to remove *Giardia* and viruses and meet EPA health risk recommendations, DHS uses total coliform numbers as a guideline for increased treatment. State guidelines for *Giardia* cyst reduction based on total coliform numbers are shown in Table 12-6. State guidelines for virus reduction are presented in Table 12-7. These guidelines are considered conservative and provide flexibility for a supplier who may disagree with this approach (DHS 1991).

Figure 12-3 shows the total coliform median values for MWDSC's Jensen and Mills FPs calculated by month over the 4-year period of the report. During this period, monthly medians at MWDSC's Jensen and Mills plants never exceeded 1,000 MPNs/100 mL. (Note that this utility provided monthly averages of its daily values. Four-year monthly medians were calculated based on these values. These 4-year monthly medians are not true medians of the data, but the overall conclusions should remain the same).

Table 12-6 Treatment Requirements for *Giardia* Cyst Reduction

Level of Microbiological Contamination[a]	Giardia cyst Treatment Requirements (Log Removals)	Monitoring Frequency
< 1,000	3	2/month
> 1,000 - 10,000	4	Weekly
>10,000 - 100,000	5	Daily

Adapted from DHS 1991

[a] Median monthly total coliform concentrations [MPN or CFU]/100 mL raw water. Levels developed with MTF method (Haberman pers. comm 2001)

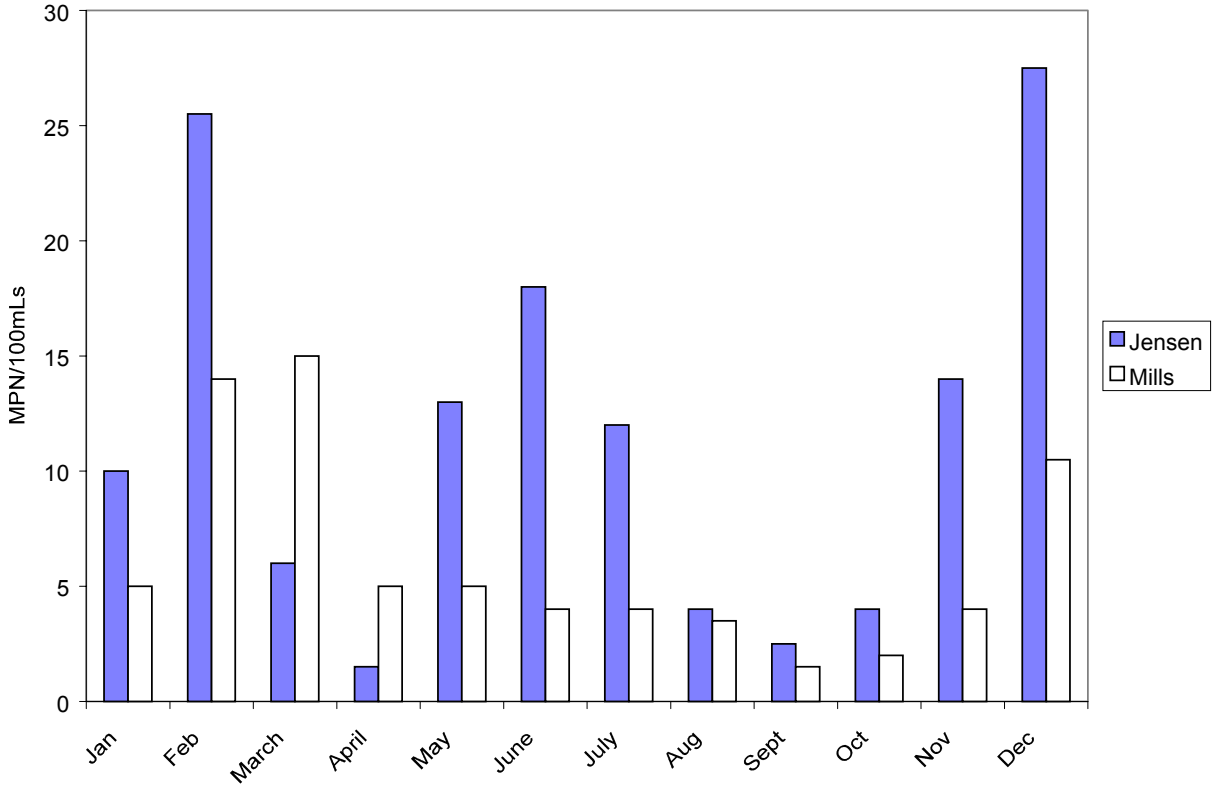
Table 12-7 Treatment Requirements for Virus Reduction

Level of Microbiological Contamination[a]	Virus Treatment Requirements (Log Removals)
< 1,000	4
> 1,000 - 10,000	5
>10,000 - 100,000	6

Adapted from DHS 1991

[a] Median monthly total coliform concentrations [MPN or CFU]/100 mL raw water

Figure 12-3 Median Total Coliform Values By Month – Jensen vs. Mills Filtration Plants, 1996 to 1999



With respect to the SBA plants, monthly medians above 1,000 MPNs/100 mL occurred the most frequently at WTP2 and least frequently at the Penitencia WTP (Figure 12-4). At least once in the years analyzed, the WTP2 monthly medians exceeded 1,000 MPN/100 mL in 9 out of 12 months. For example, in September total coliform exceeded this value for every year examined, while in October, 2 of the 3 years examined exceeded this value. In all, approximately 30% of all samples analyzed at WTP2 were $\geq$ 1,000 MPN/100 mL (Figure 12-5). At the Penitencia WTP, total coliform monthly medians never exceeded 1,000 MPN/100 mL. At this plant, all samples analyzed had total coliform densities of 300 MPN/100 mL or less (Figure 12-6). At Del Valle and Patterson Pass, total coliform monthly medians were above 1,000 MPN/100 mL generally between July through December. Based on the cumulative probability graphs, these occasions occurred in approximately 15% and 10% of the samples collected (Figures 12-7 and 12-8, respectively). Overall, Patterson Pass experienced lower total coliform densities than at Del Valle. At Patterson Pass, approximately 50% of all samples analyzed fell between 50 and 100 MPN/100 mL while at Del Valle, this same point was reached at approximately 200 MPN/100 mL.

Figure 12-4 Number of Monthly Total Coliform Medians Above or Below 1,000 MPN/100 mL for Plants Receiving SBA Water

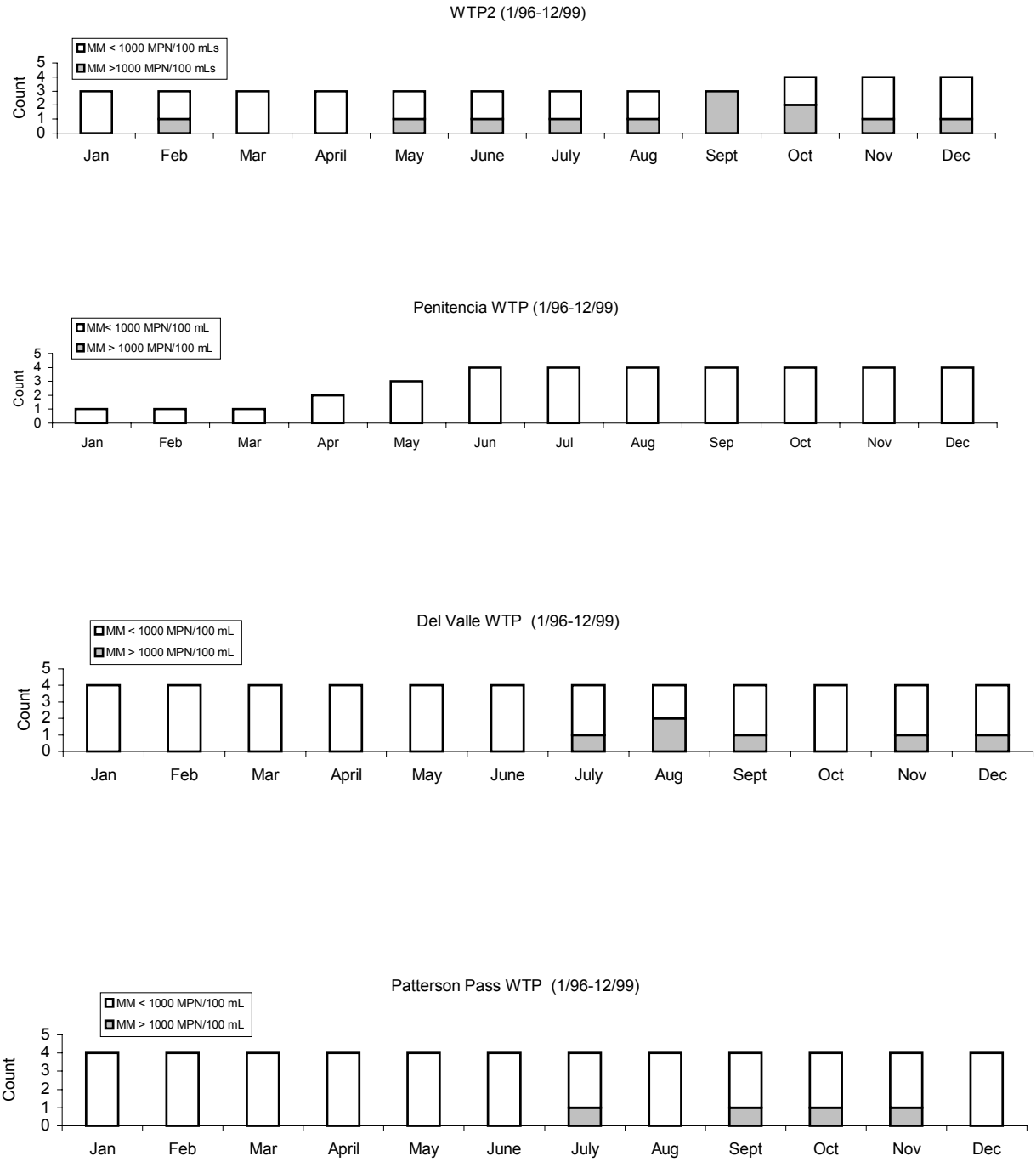
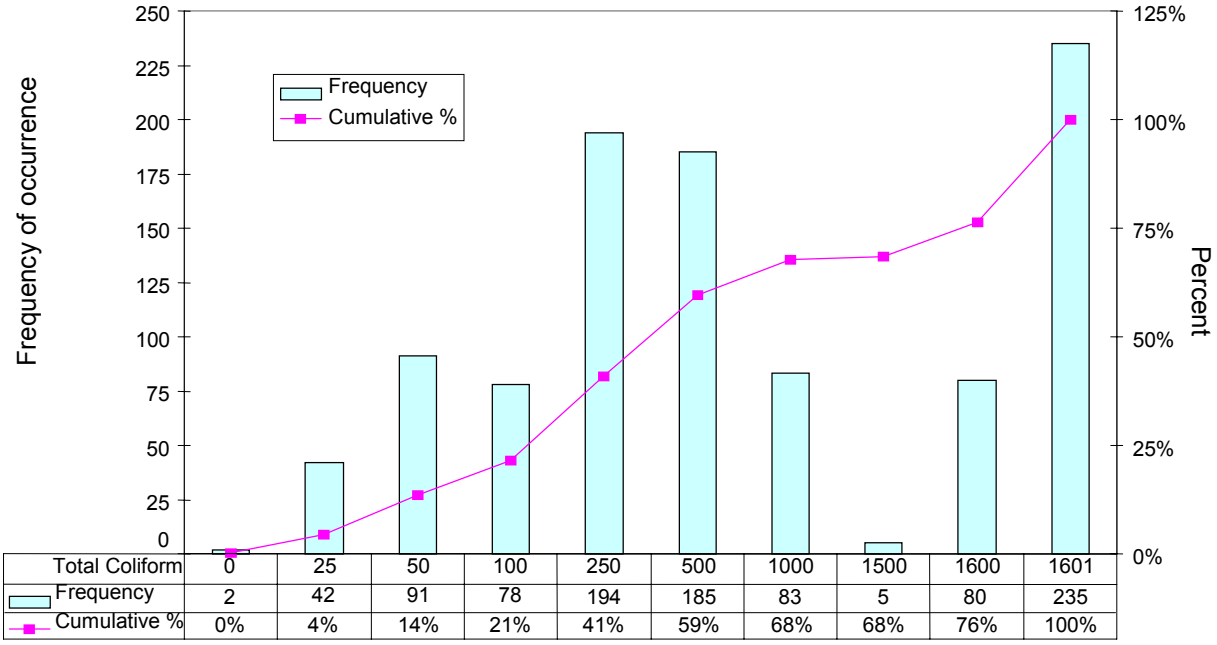
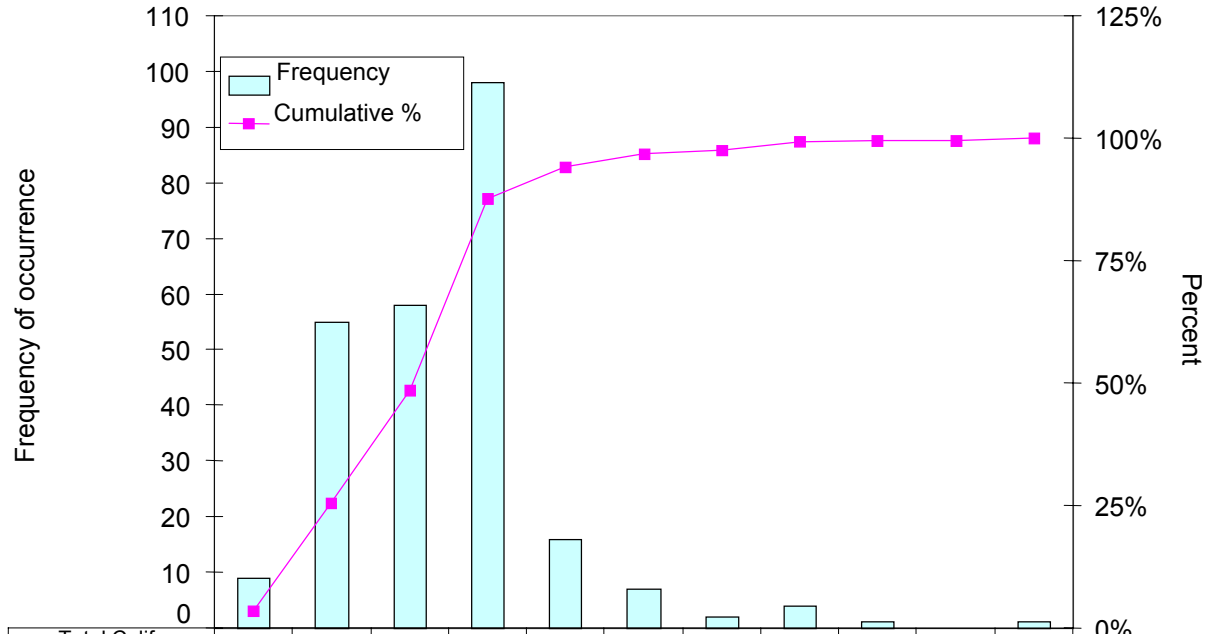


Figure 12-5 Cumulative Probability Distribution of Total Coliform Counts (MPN/100 mLs) at WTP2, Oct 1996 to Dec 1999



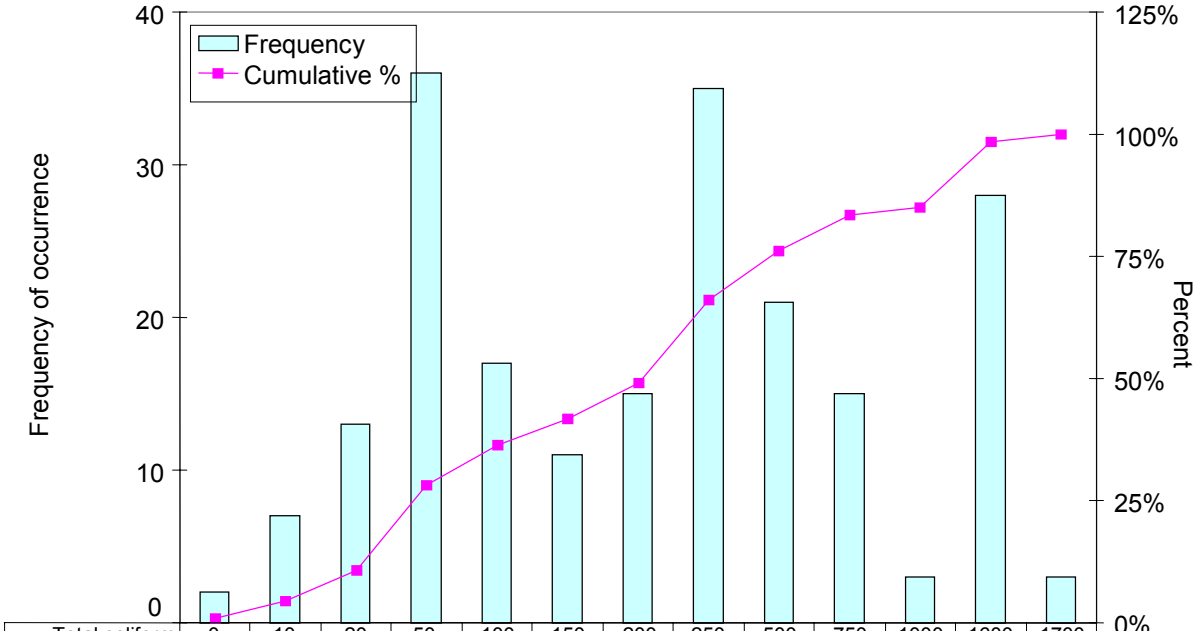
Total Coliform	0	25	50	100	250	500	1000	1500	1600	1601
Frequency	2	42	91	78	194	185	83	5	80	235
Cumulative %	0%	4%	14%	21%	41%	59%	68%	68%	76%	100%

Figure 12-6 Cumulative Probability Distribution of Total Coliform (MPN/100 mL) at the Penitencia WTP, Jan 1996 to Dec 1999



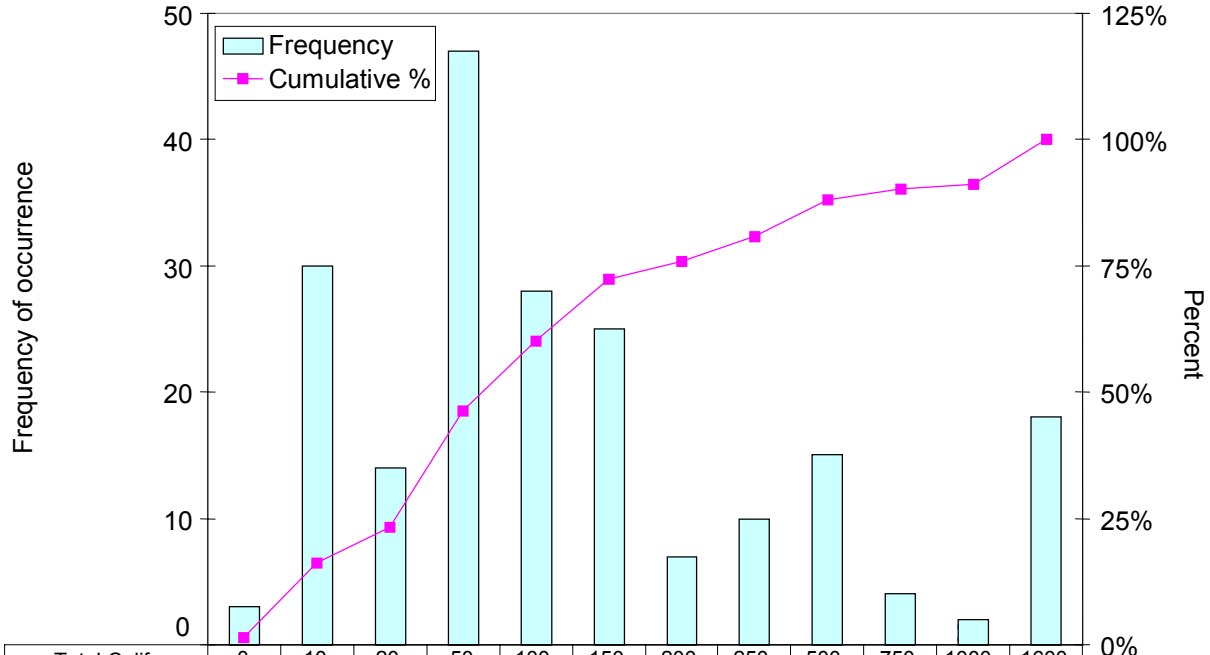
Total Coliform	0	10	20	50	100	150	200	250	300	1000	1600
Frequency	9	55	58	98	16	7	2	4	1	0	1
Cumulative %	4%	25%	49%	88%	94%	97%	98%	99%	100%	100%	100%

Figure 12-7 Cumulative Probability Distribution of Total Coliform (MPN/100 mL) at the Del Valle WTP, Jan 1996 to Dec 1999



Total coliform	0	10	20	50	100	150	200	250	500	750	1000	1600	1700
Frequency	2	7	13	36	17	11	15	35	21	15	3	28	3
Cumulative %	1%	4%	11%	28%	36%	42%	49%	66%	76%	83%	85%	99%	100%

Figure 12-8 Cumulative Probability Distribution of Total Coliform (MPN/100 mL) at the Patterson Pass WTP, Jan 1996 to Dec 1999



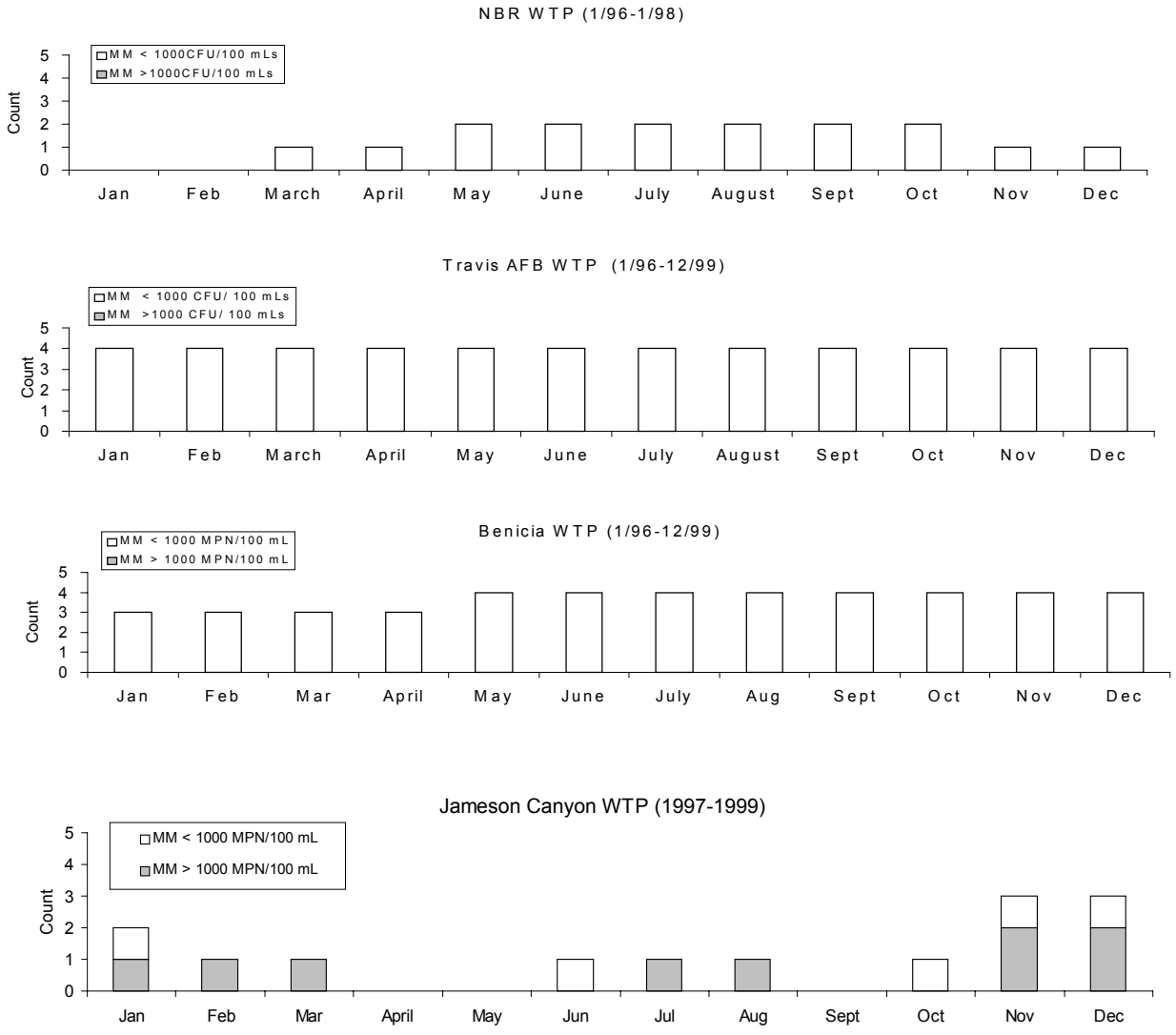
Total Coliform	0	10	20	50	100	150	200	250	500	750	1000	1600
Frequency	3	30	14	47	28	25	7	10	15	4	2	18
Cumulative %	1%	16%	23%	46%	60%	72%	76%	81%	88%	90%	91%	100%

One problem with applying total coliform guidelines to SBA results is that with the exception of the Penitencia WTP, the SBA contractor's total coliform values are based on samples analyzed by Colilert™. The guidelines, however, were developed using the MTF method (Haberman pers. comm.). Since higher total coliform densities can be an artifact of the Colilert™ method, the use of the guidelines summarized in Tables 12-6 and 12-7 could precipitate increased log reductions where none are required. The difference between the MTF and Colilert™ methods also explains why the lowest total coliform values were observed at the 1 SBA plant that did not use the Colilert™ method—the Penitencia WTP.

In contrast to the high total coliform values, *E. coli* densities of the SBA plants suggested a low level of fecal contamination (Table 12-4). Since Colilert™ and MTF are equivelent with respect to *E. coli*, the relatively low levels of *E. coli* are potentially a more fitting assessment of the level of contamination. Therefore, in the case where total coliforms were measured by Colilert™, but *E. coli* values were low, the baseline level of suggested *Giardia* removal may be more appropriate (Haberman, pers. comm.). These results also suggest that further investigations are required of the Colilert™ method to determine if its use is appropriate with these guidelines.

Of the plants using NBA waters, the Jameson Canyon WTP was the only one experiencing monthly total coliform medians above 1,000 MPN/100 mL (Figure 12-9). Monthly medians exceeded 1,000 MPN/100 mL in 7 of the 9 months samples were collected. However, in many cases, only 1 year of data was available. For all other NBA WTPs, individual samples could exceed 1,000 MPN (CFU)/100 mL; however, the monthly medians were always below this threshold. As discussed in Section 12.2.3, there is potentially a contamination problem between the Cordelia Forebay and the Jameson Canyon WTP. One simple place to test for contamination is to analyze the uncovered Napa Turnout reservoir. Additionally, investigations of American Canyon total coliform densities and further side by side comparisons with the Benicia WTP would help determine if this conclusion is correct.

Figure 12-9 Number of Monthly Total Coliform Medians Above or Below 1,000 MPN (CFU)/100 mL for Plants Receiving NBA Water

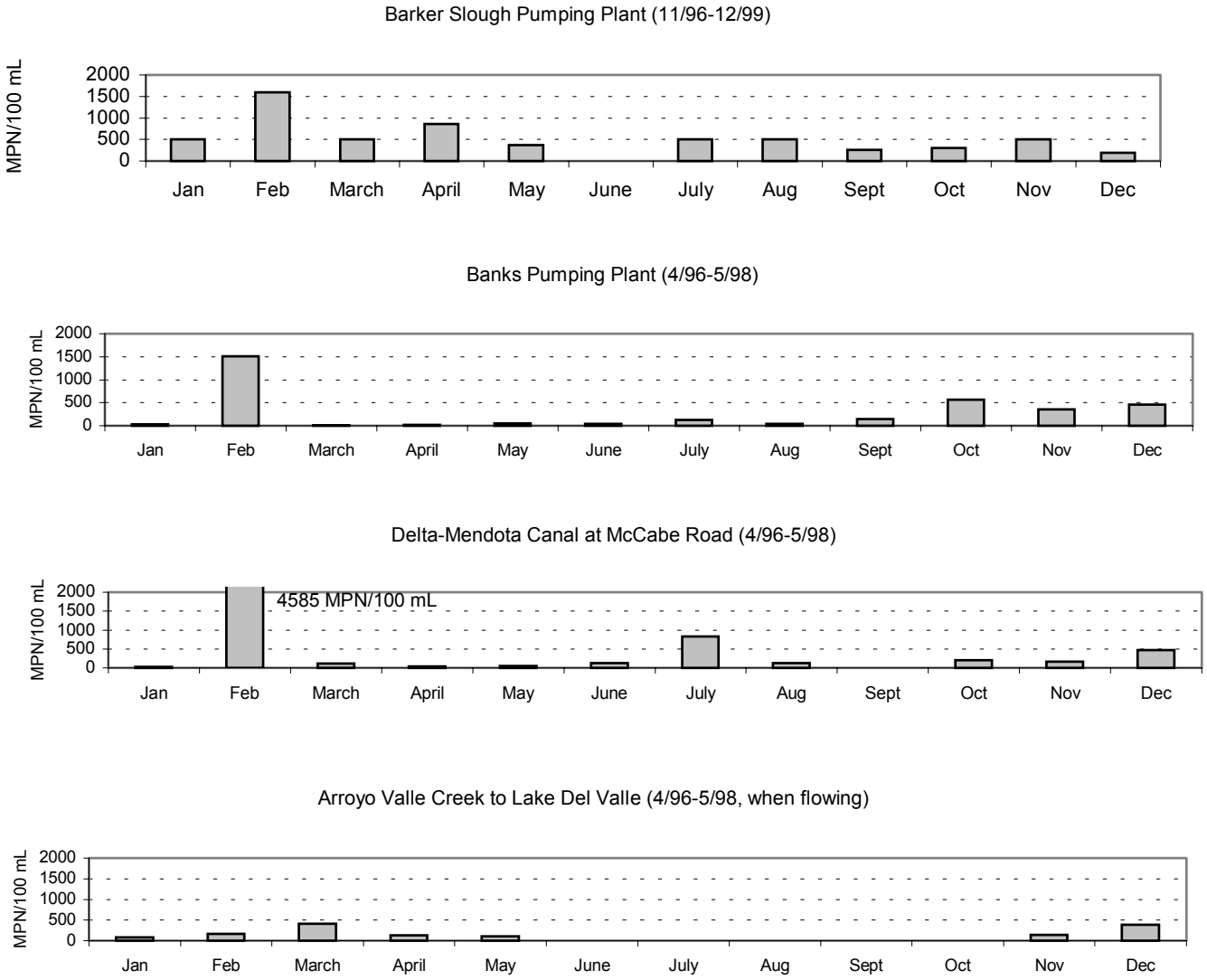


<DL changed to 0; values > DL for assay changed to upper value

With respect to samples collected by DWR, samples were collected once a month; therefore, a monthly median could not be calculated. Instead, median bacteria densities were calculated by month for the years sampled (Figure 12-10). If samples had been collected for 4 years, then a total of 4 monthly values would have been available for calculations; however, in some cases, only 2 data points were available. Barker Slough had the most data of any of the 4 DWR sample sites. With the exception of the Arroyo Valle Creek site, all sites in February experienced median total coliform values above 1,000 MPN/100 mL. Monthly medians did not exceed 1,000 MPN/100 mL for any other month of the year.

One problem associated with using total coliforms densities to suggest levels of removal of *Giardia* is that no correlation has been found between total coliform and *Giardia* densities (Pope and others 2001). The lack of correlation may be due to the relatively poor recovery and high variability associated with *Giardia* detection methods. The use of Colilert™ vs. the MTF method for total coliform analysis further clouds the issue. Therefore, until these issues are resolved, the use of this guideline may be problematic.

Figure 12-10 Monthly Median Total Coliform Values for Barker Slough PP, Banks Pumping Plant, Delta-Mendota Canal, and Arroyo Creek Inflow Into Lake Del Valle



12.3.2 RECOMMENDED REMOVAL BASED ON GIARDIA

In addition to using total coliform as a surrogate indicator for the level of *Giardia* removal, EPA published guidance on *Giardia* cyst removal based on the degree of *Giardia* contamination in the source water. These levels are shown in Table 12-8.

Table 12-8 *Giardia* Cyst Reduction Based on Source Water Concentrations

Giardia Cyst Treatment Requirements (Log Reduction)	3-log	4-log	5-log
Daily Average Cyst Concentration (Geometric Mean Cysts/100 L)	<1	>1 - 10	>10 - 100

Source: EPA 1989

None of the profile plants collected daily samples for *Giardia* analysis. In most cases monthly samples were collected. Additionally, samples were not necessarily collected over the entire period of record.

The cyst reduction based on suggested EPA guidelines in Table 12-8 were compared to the cyst reductions suggested by total coliform concentrations in Table 12-6. Based on the data available, summary statistics of *Giardia* cyst concentrations are shown in Table 12-9. Medians were calculated instead of geometric means due to values less than the detection limit. The majority of *Giardia* results were determined using the ICR method. The ICR method has been criticized for its high rates of false positives and negatives as well as its lack of sensitivity. Because of the method's limitations, it is unknown whether the data presented in Table 12-9 presents a true picture of the *Giardia* environment. For example, for every plant profiled, the median *Giardia* concentration was below the detection limit, while the percentage of nondetects at all locations ranged from 84% to 100%.

Table 12-9 *Giardia* Cyst Concentrations (cysts/100L) for Sites Sampled by DWR and Selected Water Treatment Plants Receiving Only SWP Water (Except Where Noted, All Samples Analyzed by ICR IFA)

Agency	Location	Median	Min	Max	Percentile Range (10-90%)	Number Detects/ Total Sampled	Percent nondetect
DWR	Barker Slough Pumping Plant[a]	<DL	< DL	75	< DL - 40	14/42	67
	Banks Pumping Plant[b]	<DL	< DL	34	<DL - <DL	1/23	96
	Delta-Mendota Canal @ McCabe Road[b]	<DL	<DL	<DL	<DL - <DL	0/21	100
	Arroyo Valle Creek Inflow to Lake Del Valle[d]	<DL	<DL	2	<DL - <DL	1/12	92
MWDSC	Jensen Filtration Plant[e]	<DL	< DL	4.11	<DL - <DL	2/48	96
	Mills Filtration Plant[e]	<DL	< DL	346.5	0 - 4.18	6/48	88
NBA	City of Benicia WTP	-					
	Jameson Canyon WTP (Napa)	-					
	North Bay Regional WTP (Fairfield, Vacaville)[e]	<DL	<DL	123	< DL - 42	1/7	86
	Travis Air Force Base WTP (Vallejo)	-					
SBA	Penitencia WTP[f]	<DL	< DL	< DL	<DL - <DL	0/17	100
	Del Valle WTP[f]	<DL	< DL	< DL	<DL - <DL	0/16	100
	Patterson Pass WTP[f]	<DL	< DL	<DL	<DL - <DL	0/31	100
	WTP2[f]	<DL	<DL	25	<DL - <DL	1/17	84

[a] Samples generally collected monthly from Oct 1996 to Dec 1999, no samples collected Jun 1998. Monthly sampling to continue indefinitely.
[b] Samples collected monthly from Jul 1996 to May 1998, no samples collected since May 1998.
[c] Samples collected monthly from Jul 1996 to May 1998 unless no flow.
[d] Samples collected monthly from Jan 1996 to Dec 1999. Samples analyzed by Method 1623 beginning 1999.
[e] Samples collected monthly from Jul 1997 to Dec 1998 when plant receiving NBA water.
[f] Samples collected monthly from Jul 1997 to Dec 1998.
Summary Statistics calculated by substituting 0 for all values less than the detection limit
<DL = less than the detection limit

Method 1623 was introduced in 1999 to provide a more robust method to analyze for pathogens. The method is generally not as susceptible to false positives as the ICR methodology and its recovery rates, based on spiked samples, are also substantially higher. MWDSC began using Method 1623 in 1999. However, even with 1623 analysis, no *Giardia* was detected at MWDSC's Jensen and Mills FPs. Method 1623 data were not available from the other WTPs. For samples collected from Barker Slough by DWR, Method 1623 data were only available for the last 5 months of 1999. With so few data points, these data were not used for calculations. For comparative purposes, the results of the 2 methods are shown below (Table 12-10).

Table 12-10 *Giardia* Concentrations at the Barker Slough Pumping Plant Using ICR IFA and Method 1623[a]

Date Sampled	ICR IFA (cysts/100 L)[b]	Method 1623 (cysts/L)
31 Aug 1999	0	0
21 Sep 1999	0	0
25 Oct 1999	44	0
29 Nov 1999	0	0
28 Dec 1999	0	0.05 [c]

[a] All values less than the detection limit changed to 0.
[b] Information Collection Rule Immonufluorescent Assay (ICR IFA).
[c] Average of duplicate analysis.

The original purpose of this section was to compare log reductions suggested by total coliform numbers against log reductions suggested by actual *Giardia* concentrations. Due to the limited data set (that is, lack of daily geometric means) and the uncertainty of the reliability of the data, this comparison was not realistic.

Although false positives and recovery are a problem with the ICR method, the method may be useful as a frequency of occurrence indicator rather than as an absolute number. To determine if there were any seasonal patterns of *Giardia* occurrence, WTPs and DWR facilities with 2 or more *Giardia* detections were graphed (Figures 12-11 and 12-12). With respect to the Jensen FP, *Giardia* was detected once in September and November (although not necessarily in the same year). With respect to the Mills FP, 4 of the 6 detections occurred between December and March (although again, not necessarily in the same year).

The relationship between *Giardia* detections and season were stronger for samples collected from the Barker Slough Pumping Plant. With the exception of 2 samples, 10 of the 14 detections at the Barker Slough Pumping Plant occurred between December and March. Unlike the Jensen and Mills FPs these results were consistent from year to year. This lends credibility to the hypothesis that the most frequent *Giardia* occurrences at the Barker Slough Pumping Plant occur in the winter; however, the increase in false positives from storm water debris must be considered.

Figure 12-11 *Giardia* Concentration (cysts/100 L) at Jensen and Mills Filtration Plants, Jan 1996 to Dec 1999

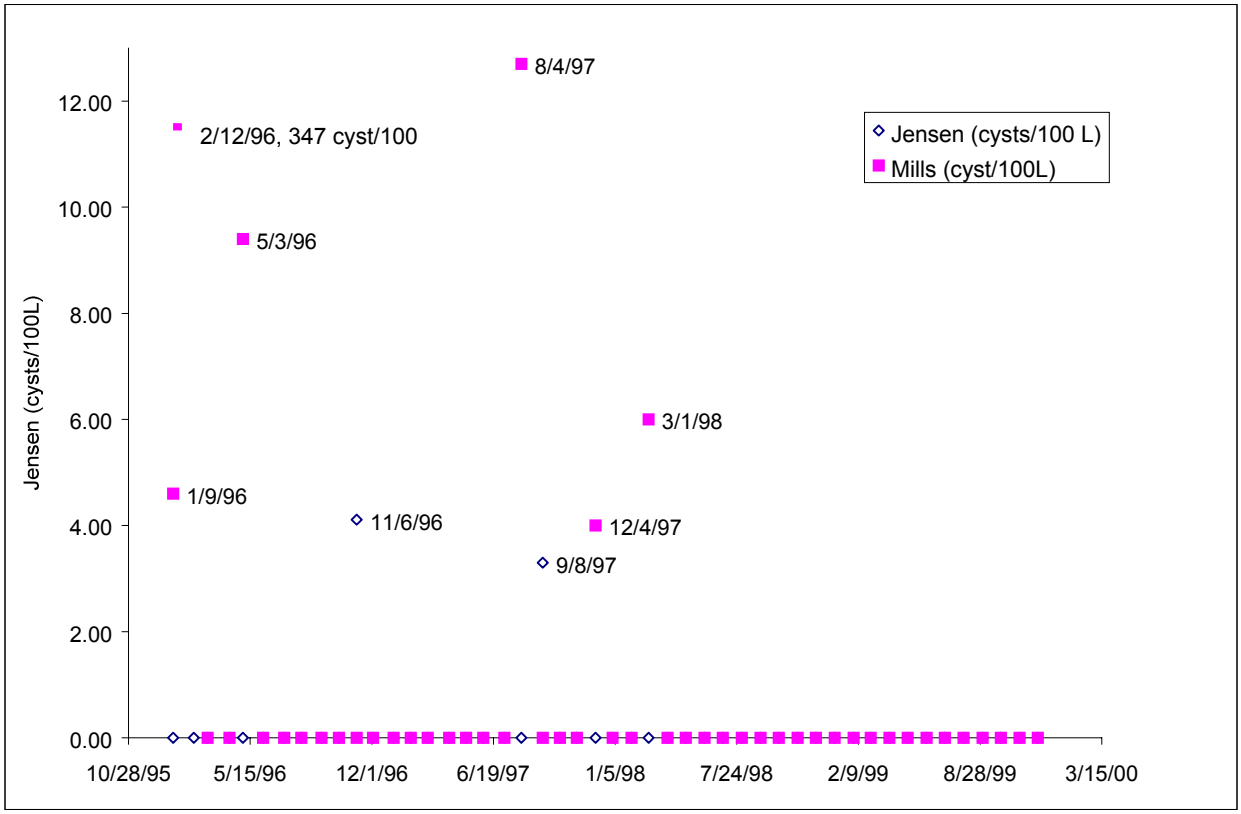
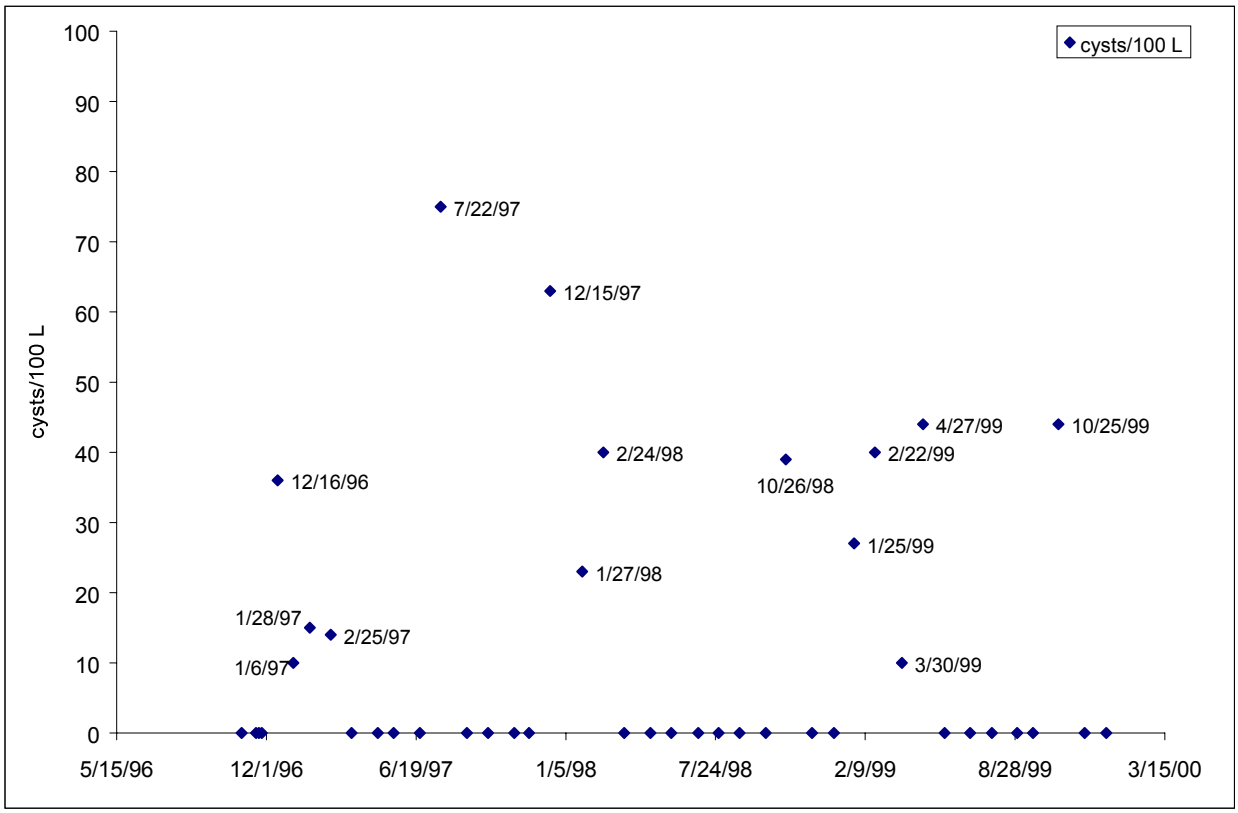


Figure 12-12 *Giardia* Concentration (cysts/100 L) at the Barker Slough Pumping Plant, Oct 1996 to Dec 1999



12.4 *CRYPTOSPORIDIUM*

In this section, the highest 12-month running average for *Cryptosporidium* monthly samples for the profiled WTPs, was compared to the "bin" log removals proposed in the Stage 2 Microbial Disinfection Byproducts Agreement in Principle (AIP) (Tables 12-11 and 12-12). In the future, this approach will be used to determine the level of log removals of *Cryptosporidium* oocysts (if any) at a WTP (EPA 2000). A 2nd approach also endorsed by the Stage 2 AIP is the calculation of a monthly average from 2 samples collected monthly over a 1-year period. This approach was not used as *Cryptosporidium* numbers had not been analyzed twice a month by any utility.

Table 12-11 Treatment Requirements for *Cryptosporidium* Removal Under the Stage 2 Microbial Disinfection Byproducts Agreement in Principle

Bin #	Avg. Cryptosporidium Concentration (oocyst/L)	Additional Treatment Requirements[a]	Final Log Removal Achieved by Meeting IESWTR & Stage 2 Additional Requirements
1	Cryptosporidium < 0.075/L	None	3
2	0.075/L > Cryptosporidium <1.0/L	1-Log	4
3	1.0/L > Cryptosporidium <3.0/L	2-Log	5
4	Cryptosporidium > 3.0/L	2.5-Log	5.5

Adapted from EPA 2000

[a] Additional treatment requirements are for systems with conventional treatment that are in full compliance with the Interim Enhanced Surface Water Treatment Rule (IESWTR).

Table 12-12 Highest 12-Month Running Average Value for *Cryptosporidium* Concentrations (oocysts/L) for Sites Sampled by DWR and Selected Water Treatment Plants Receiving Only SWP Water
(Except where noted, all data analyzed by ICR IFA)

Agency	Location	1996-97	1997-98	1998-99
DWR	Barker Slough Pumping Plant[a]	-	0.091	0.1
	Banks Pumping Plant[b]	0.14	-	-
	Delta Mendota Canal @ McCabe Road[b]	0	-	-
	Arroyo Valle Creek Inflow to Lake Del Valle	-	-	-
MWDSC	Jensen Filtration Plant[c]	0.01	0	0
	Mills Filtration Plant[c]	0.22	0.01	0.01
NBA	City of Benicia WTP	-	-	-
	Jameson Canyon WTP (Napa)	-	-	-
	North Bay Regional WTP (Fairfield, Vacaville) [d]	-	-	-
	Travis Air Force Base WTP (Vallejo)	-	-	-
SBA	Penitencia WTP			
	Del Valle WTP[e]	-	0	-
	Patterson Pass WTP[e]	-	0	-
	WTP2[f]	-	0	-

[a] Samples collected monthly. Used data from Jan 1997 to Nov 1998 and Jan 1998 to Nov 1999.
[b] Samples collected monthly. Used data from Jul 1996 to May 1998.
[c] Samples collected monthly. Used data from Jan 1996 to Nov 1997, Jan 1997 to Nov 1998, and from Jan 1998 to Nov 1999. Method 1623 used starting Jan 1999.
[d] Insufficient number of samples to calculate running average.
[e] Samples collected monthly. Used data from Jan 1997 to Nov 1998.
[f] Samples collected monthly. Used data from Jul 1997 to Dec 1998.
Notes: Summary Statistics calculated by substituting 0 for all values less than the detection limit.
- = data not available or incomplete.

Based on data available, not all Stage 2 AIP specifications for calculating running averages could be met. For example, ICR data were primary sources for most *Cryptosporidium* calculations. The Stage 2 agreement recommends calculating the 12-month running average using 2 full years of data; however, with ICR data, 2 years of data were not available (ICR data were collected from July to December 1998). In some cases, plants had been collecting monthly *Cryptosporidium* data prior to the ICR survey. These data were used whenever possible. In addition, under the Stage 2 agreement, *Cryptosporidium* concentrations were to be calculated using Method 1623. With the exception of MWDSC's Jensen and Mills FPs, Method 1623 data were not available for the WTPs. MWDSC began analyzing *Cryptosporidium* concentrations by Method 1623 in January 1999. These data were used for calculating Jensen and Mills running averages for the 1998 to 1999 two-year period. Running annual averages could not be computed for NBA contractors because only 7 samples were analyzed for *Cryptosporidium* using SWP water.

With 1 exception, *Cryptosporidium* concentrations at the WTPs fell within the 1st bin range of < 0.075 oocysts/L (Table 12-12). Using ICR data and Stage 2 AIP specifications, these results indicate no further treatment would be required beyond a plant meeting the Interim Enhanced Surface Water Treatment Rule (IESWTR) regulations. The 1 exception was the Mills FP. The highest 12-month running average at Mills FP in 1996/1997 was 22 times higher than averages calculated for the 1997/1998 and 1998/1999 seasons. The subsequent years, when running

averages were lower, suggest that basing decisions on a single 2-year sampling period may be inadequate.

Tracking 12-month running averages over a 4- or 6-year period may prove more useful in determining whether higher averages are a 1-time occurrence or a long-term trend. However, because samples collected in 1996/1997 were analyzed by the ICR method, another possibility is that false positives may have incorrectly inflated oocyst concentrations and created a false difference between years. Because actual comparisons will be made using Method 1623 data, this may not be an issue. Additionally, using a single 2-year average to determine oocyst watershed concentrations potentially represents oocyst mobilization only under particular conditions. For example, water years from 1996 to 1999 were wet or above normal. Data generated from above-average water years may provide the most conservative estimate of the level of protection a treatment plant should achieve. However, if oocyst concentrations are generated during a drought period with little runoff, a false sense of confidence could be achieved. In these cases, it would be advisable for a plant to continue sampling for *Cryptosporidium* so that running averages incorporating above-normal rainfall years can also be determined.

Running averages were also calculated for the 4 sites analyzed by DWR. Oocyst concentrations at the Barker Slough Pumping Plant were above 0.075 oocysts/L, but below 1 oocyst/L (bin 2).

Cryptosporidium oocysts were detected above 0.075 oocysts/L at the Banks Pumping Plant. How this concentration relates to WTPs that receive SWP water is unknown. No oocysts were detected in the Arroyo Valle Creek inflow to Lake Del Valle.

12.5 LONG TERM 2 ENHANCED SURFACE WATER TREATMENT RULE MICROBIAL INDEX

Using data collected from the ICR and the Supplemental Survey, the EPA developed a microbial index for reservoir/lake and running stream water sources (Pope and others 2001). For small systems, the expense and difficulty of analyzing samples for *Cryptosporidium* can be prohibitive; therefore, 1 of the issues examined by the EPA was the possibility of using a microbial index to assess a source water's vulnerability to high *Cryptosporidium* concentrations.

The goal of the LT2 ESWTR Microbial Index is to identify watersheds with potentially high concentrations of *Cryptosporidium* using fecal contamination as an indicator of risk. One misconception is that the presence of the indicator organism is statistically correlated with *Cryptosporidium* occurrences. This is not correct. Based on ICR and Supplemental Survey data, there is not a good correlation between coliform and *Cryptosporidium* concentrations (Pope pers. comm.). Instead, the indicator organism is used to identify a level of fecal contamination that signals a warning to the analyst that enough fecal contamination may be present in the watershed to warrant *Cryptosporidium* monitoring. At a certain level, watersheds that have fecal contamination may or may not have *Cryptosporidium* contamination. However, watersheds without fecal contamination should not have *Cryptosporidium* contamination. For several reasons, *E. coli* was initially chosen as the microbial indicator organism because of its use as an indicator of fecal contamination.

Analyses of ICR and Supplemental Survey data suggest that concentrations of 5 to 10 *E. coli*/100 mL from WTPs receiving water from a reservoir/lake may indicate a water source is vulnerable to *Cryptosporidium* contamination. For WTPs receiving water from a flowing stream, *E. coli* levels of 50 organisms/100 mL may indicate vulnerability to *Cryptosporidium* contamination. These initial values are based on ICR and Supplemental Survey datasets, which have a number of weaknesses that compromise their results and, in turn, affect the conclusions reached by the microbial index. One reason for the *Cryptosporidium* and *E. coli* monitoring with the promulgation of Stage 2 is to develop a more robust dataset. Therefore, *E. coli* and *Cryptosporidium* trigger and bin values could change as data from Stage 2 pathogen monitoring are analyzed. However, until the Stage 2 monitoring is complete, these index values are the only analyses available to assess watershed vulnerability to *Cryptosporidium* contamination.

For this report, 6 of the 7 WTPs with *Cryptosporidium* data were classified into WTPs receiving their water from either a reservoir/lake or a flowing stream. (NBR data were not used because of the lack of oocyst data from SWP water). Technically, 1 of the original water sources for all WTPs profiled is either the Delta or a watershed tributary to the Delta. For this report, Delta water stored or passed through a reservoir or lake was classified under the reservoir/lake category. Water that passed through surge tanks was not classified under the reservoir/lake category because surge tanks are not designed for storage but to dampen sudden changes in water pressure through a pipeline. Also, all the systems listed in this report are medium to large systems; therefore, all would be required to monitor for *Cryptosporidium* regardless of their *E. coli* levels. These data were used in this report simply to examine the bin and microbial index approaches.

In calculating its microbial index, the EPA used mean *E. coli* concentrations; therefore, in general, average *E. coli* values were calculated over the same period as a plant's *Cryptosporidium* 12-month running average. Like running average data, *E. coli* data that corresponded to *Cryptosporidium* sampling were mostly available from ICR data. Therefore, in most cases, a full 2 years of data were not available for analysis. The 1 exception was *E. coli* data from Zone 7's Del Valle and Patterson Pass WTPs. For these plants, *E. coli* data were available for samples collected from the ICR survey beginning in July 1997. A full year of *Cryptosporidium* monitoring was available beginning in January 1997. Because *Cryptosporidium* was not detected at the plants in 1997 or 1998, the absence of 6 months of *E. coli* data may not be critical. With these caveats, 12-month running averages and average *E. coli* concentrations are shown in Table 12-13.

E. coli density data presented in Table 12-13 were compared to the *E. coli* microbial index criteria of 50 organisms/100 mL for plants receiving water from flowing streams and a range of 5 to 10 organisms per 100 mL for plants receiving water from a reservior or lake. These comparisons were used to determine whether fecal contamination was high enough to warrant further monitoring for *Cryptosporidium*. This conclusion was then compared to the plant's theoretical bin assignment determined from the *Cryptosporidium* highest 12-month running average in Table 12-13. Table 12-14 shows the comparison between a plant's bin assignment based on *Cryptosporidium* concentrations from source water monitoring and whether further *Cryptosporidium* monitoring would be required based on the microbial index.

Table 12-13 Highest *Cryptosporidium* Annual Running Average Values and Corresponding Average *E. coli* Values for Sites Sampled by DWR and Selected Water Treatment Plants Receiving Only SWP Water

			1996-97		1997-98		1998-99	
Agency	Location	Waterbody Type	Highest *Cryptosporidium* 12 Month Running Avg (oocysts/L)	Avg *E. Coli* Concentration (MPN/ 100 mL)	Highest *Cryptosporidium* 12 Month Running Avg (oocysts/L)	Avg. *E. Coli* Concentration (MPN/100 mL)	Highest *Cryptosporidium* 12 Month Running Avg (oocysts/L)	Avg. *E. Coli* Concentration (MPN/100 mL)
DWR	Barker Slough PP[a]	Flowing Stream	-	-		360	0.1	306
	Banks PP[b]	Flowing Stream	0.14	Not analyzed	-	-	-	-
	DMC @ McCabe Road[b]	Flowing Stream	0	Not analyzed	-	-	-	-
	Arroyo Valle Creek Inflow to Lake Del Valle	Flowing Stream	-	Not analyzed	-	-	-	-
MWDSC	Jensen Filtration Plant[c]	Reservoir/ Lake	0.01	0	0	4	0	23
	Mills Filtration Plant[c]	Reservoir/ Lake	0.22	8	0.01	2	0.01	1
NBA	City of Benicia WTP	-	-	-	-	-	-	-
	Jameson Canyon WTP (Napa)	-	-	-	-	-	-	-
	North Bay Regional WTP (Fairfield, Vacaville)	Flowing Stream	-	-	-	-	-	-
	Travis AFB WTP (Vallejo)	-	-	-	-	-	-	-
SBA	Penitencia WTP[d*]	Flowing Stream and reservoir/lake	-	-	0.01	7	-	-
	Del Valle WTP[e]	Flowing Stream	-	-	0	12	-	-
	Patterson Pass WTP[e]	Flowing Stream	-	-	0	12	-	-
	WTP2[d]	Flowing Stream	-	-	0	14	-	-

Cryptosporidium Vulnerability Suggested by average *E. coli* concentrations of: Flowing stream = 50 org/100 mLs; Reservoir/Lake = 5-10 org/100 mLs; - = data not available or incomplete.
Summary Statistics calculated by substituting 0 for all values less than the detection limit.

[a] Samples collected monthly. Used data from Jan 1997 to Nov 1998 and Jan 1998 to Nov 1999.
[b] Samples collected monthly Used data from Jul 1996 to May 1998.
[c] Samples collected monthly. Used data Jan 1996 to Nov 1997, Jan 1997 to Nov 1998, and Jan 1998 to Nov 1999.
[d] Samples collected monthly. Used data from Jul 1997 to Dec 1998
[e] Samples collected monthly. Used data from Jan 1997 to Nov 1998.
* Water body varied by sample date.

Table 12-14 Comparison Between Stage 2 Bin Ranges and *E. coli* Microbial Index

Agency	Location	Waterbody Type	Additional Treatment Based on Bin Range?	Additional Cryptosporidium Monitoring Based on Index?
DWR	Barker Slough Pumping Plant	Flowing Stream	Not applicable	Yes
	Bank's Pumping Plant	Flowing Stream		
	Delta Mendota Canal @ McCabe Road	Flowing Stream		
	Arroyo Valle Creek Inflow to Lake Del Valle	Flowing Stream		
MWDSC	Jensen Filtration Plant	Reservoir/Lake	No	Maybe (depending on sample year)
	Mills Filtration Plant	Reservoir/Lake	Maybe	Maybe (depending on sample year)
NBA	City of Benicia WTP	-		
	Jameson Canyon WTP (Napa)	-		
	North Bay Regional WTP (Fairfield, Vacaville)	Flowing Stream	-	-
	Travis Air Force Base WTP (Vallejo)	-		
SBA	Penitencia WTP[a]	Flowing Stream and Reservoir/Lake	No	-
	Del Valle WTP	Flowing Stream	No	No
	Patterson Pass WTP	Flowing Stream	No	No
	WTP2	Flowing Stream	No	No

[a] Waterbody type varied by sample date. Unable to determine appropriate Index value for comparisons.

The microbial index and *Cryptosporidium* log-removal based on the WTP's bin were generally in agreement. In the case where the bin suggested greater treatment (Mills FP, 1996 to 1997), the microbial index also indicated that fecal contamination was high enough to warrant further monitoring. The 1 exception between the 2 techniques occurred with samples collected at Jensen FP between 1998 and 1999. In this period, no *Cryptosporidium* were detected at the treatment plant; however, the microbial index indicated the potential for *Cryptosporidium* contamination. These results do not mean that *Cryptosporidium* contamination was present, but that there was that possibility. If these had been the *E. coli* results from a small system, subsequent *Cryptosporidium* monitoring would be required. However, under this system, the microbial index numbers are simply indicators. Actual *Cryptosporidium* values are the final arbiter as to whether there is a *Cryptosporidium* problem.

12.6 STUDIES OF HEALTH RISKS RESULTING FROM BODY-CONTACT RECREATION IN SOUTHERN CALIFORNIA SWP RESERVOIRS

The California Water Code allows body-contact recreation on reservoirs constructed and operated as part of the SWP to the extent that it is compatible with public health and safety requirements (California Water Code, Section 12944(a)). In the 1980s and 1990s, both *Cryptosporidium* and *Giardia* were identified as important causitive agents in waterborne disease. Unfortunately, because of the difficulties and costs associated with *Cryptosporidium* and *Giardia* sampling and detection, little information is available on the

importance of this source of pathogens to surface waters. One of the problems with using coliform as surrogates for *Cryptosporidium* and *Giardia*, is that both protozoa are more resistant to environmental conditions. Coliforms tend to die off quickly outside a host's body, while protozoan can remain viable for several weeks. Since fecal shedding and accidental fecal releases by infected individuals can result in high numbers of pathogens shed into a water body, it is important to understand the potential health implications resulting from body-contact recreation on reservoirs used as a source drinking water. Recently, model simulations have been used to estimate pathogen concentrations in source drinking water reservoirs impacted by recreation.

In 1995, the MWDSC commissioned a microbiological risk assessment study for its new Eastside Reservoir in Riverside County to examine the health risk impacts and appropriate levels of recreation from the impacts of various recreation use scenarios (Yates and others 1997). The study incorporated published data on the infection rate of individuals as a function of age, pathogen inactivation rates, and other data to produce probabilistic descriptions of predicted pathogen concentrations in the reservoir. Data from these analyses produced predicted pathogen concentrations, which were then used with dose response models to predict probability of risk of infection to consumers (Yates and others 1997).

The DHS requested that a similar analysis be conducted on 4 Southern California SWP Reservoirs—Castaic Lake, Lake Perris, Pyramid Lake, and Silverwood Lake. Through the State Water Contractors, Dr. Michael Anderson of UC Riverside was contracted to predict, based on the MWDSC study, the impact of body-contract recreation on water quality in the reservoirs. The full report is included as Appendix A. What follows is a summary of Dr. Anderson's findings.

Based on Anderson's calculations, recreational use ranking by lake (highest to lowest) were Lake Perris, Castaic Lake, Pyramid Lake, Silverwood Lake. With the exception of predicted rotavirus numbers at Castaic and Pyramid lakes, predicted pathogen levels also reflected higher pathogen numbers with increased recreational use (Table 12-15).

At the median concentration, 50% of the predicted pathogen concentrations would fall above or below this value. At the 95% density, only 5% of the predicted concentrations would lie above this value. The 95% value is more protective of public health.

To determine the probability of exceeding the EPA's target of 1 infection per 10,000 consumers, Anderson used the median and 95% predicted pathogen concentrations listed in Table 12-15 to calculate health risks to consumers from body-contact recreation in the respective SWP reservoirs. With this approach, the probability of contracting an infection or illness is a function of both the exposure and the infectivity of the pathogen. Exposure to consumers is governed by the pathogen concentration in the source water, any inactivation during transit from reservoir to the treatment plant, and the removal efficiency at the treatment plant. As part of his calculations, Anderson used the 2-log *Cryptosporidium* removal efficiency that conventional WTPs were assumed to meet under IESWTR turbidity requirements. For *Giardia* and viruses the removal efficiency is 3- and 4-log removals, respectively. Based on Anderson's calculations, the annual risk of infection per 10,000 consumers at both the 50% (median) and 95% predicted pathogen concentrations are shown in Table 12-16.

Table 12-15 Median and 95% Predicted Annual Average of Pathogen Levels at 4 Southern California SWP Reservoirs (95% given in parentheses)

	Lake Perris	Castaic Lake	Pyramid Lake	Silverwood Lake
Cryptosporidium (oocyst/100L)	0.85 (16.6)	0.43 (8.3)	0.31 (6.08)	0.22 (4.41)
Giardia (cyst/100L)	0.031 (0.8)	0.016 (0.4)	0.01 (0.29)	0.008 (NA)
Poliovirus (pfu/100L)	5.7 (44)	2.9 (22.3)	2.1 (16.3)	1.5 (NA)
Rotavirus (pfu/100L)	267 (3055)	13.4 (1530)	98 (120)	71 (NA)

Adapted from Anderson 2000
NA = Data not sufficient to compute statistic

Table 12-16 Predicted Consumer Risk Assessment (Infections/10,000 consumers/year) at 4 Southern California SWP Reservoirs at 50% and 95% Probabilities (95% given in parentheses)[a]

	Lake Perris	Castaic Lake	Pyramid Lake	Silverwood Lake
Cryptosporidium	2.39 (46.6)	1.20 (23.4)	0.88 (17.1)	0.64 (12.4)
Giardia (cyst/100L)	0.0115 (NG)	0.0058 (NG)	0.0042 (NG)	0.0031 (NG)
Poliovirus (pfu/100L)	NA	NA	NA	NA
Rotavirus (pfu/100L)	NG	NG	NG	NG

Adapted from Anderson 2000

[a]Assuming 2-log Removal Efficiency for *Cryptosporidium*, 3-log Removal Efficiency for *Giardia*, and 4-log Removal Efficiency for Viruses.

NA = not analyzed, NG = analyzed but no numbers given

Under this scenario, the median risk of infection for *Cryptosporidium* exceeds EPA levels of 1 infection/10,000 consumers/year at lakes Perris and Castaic. *Cryptosporidium* standards are not exceeded at Pyramid and Silverwood lakes. At the 95% probability, all lakes exceeded EPA levels. With respect to *Giardia*, all lakes fell below EPA's annual risk of infection. Anderson noted that even using the 99% level of predicted *Giardia* concentrations, the risk of infection from *Giardia* remained below 1 infection/10,000/year.

Anderson gave no numbers of predicted risk of infection values for rotavirus or poliovirus. He noted that with respect to rotavirus, the model predicted median infection rates of up to hundreds of infections per 10,000 per year. Moreover, community health and other data suggested lower rates of infection than predicted. The capacity for virus removal at MWDSC plants above 4-logs led MWDSC to discount rotavirus as a risk to water consumers (Anderson 2000). Nevertheless, even with reduced shedding rates, rotavirus remains a concern (Anderson 2000). With respect to poliovirus, calculations were not possible because of the lack of suitable dose-response models in the literature. It was also suggested that poliovirus may be a minimal health risk to water consumers based on its lower concentrations relative to rotavirus and MWDSC's ability to remove viruses above 4-logs.

Like any model, predicted values are subject to the limitations regarding the assumptions made and quality of the data being used. Anderson (2000) identifies the following limitations:

1) Differences in recreational use patterns and limnological features among the lakes that were not adjusted for (for example, lakes with limited body-contact recreation vs. lakes with greater body-contact recreation),
2) Difference in age distributions of the recreation population (for example, children vs. adults),
3) Differences in treatment efficiencies of the WTPs receiving lake water,
4) The additivity of risks,
5) Seasonal effects on risk values, and
6) Other inputs of pathogens to the lake.

For most of the limitations listed above, the data may be lacking to refine the model. Stage 2 Microbial Disinfection Byproducts AIP notes that conventional WTPs meeting IESWTR turbidity requirements would achieve 3-log removal of *Cryptosporidium*, not the 2-log removal assumed by the IESWTR and used by Anderson for calculations of risk assessment. If the remaining variables in the model remain the same, then the annual level of risk of *Cryptosporidium* infection per 10,000 consumers falls by a factor of 10. If this is the case, then the risk of infection at the 50% probability level from *Cryptosporidium* at all SWP Southern California reservoirs falls below the EPA's 1 in 10,000/year (Table 12-17).

Table 12-17 Predicted Consumer Risk Assessment (Infections/10,000 consumers/year) at 4 Southern California SWP Reservoirs at 50% and 95% Probabilities (95% given in parentheses) Under 2-log and 3-log Removal Efficiency for *Cryptosporidium*

	2-log removal	3-log removal
Lake Perris	2.39 (46.6)	0.239 (4.66)
Castaic Lake	1.20 (23.4)	0.120 (2.34)
Pyramid Lake	0.88 (17.1)	0.088 (1.71)
Silverwood Lake	0.64 (12.4)	0.064 (1.24)

Although at the 50% median concentration *Cryptosporidium* levels fall below EPA's infective levels, at the 95% concentration all sites are still above 1 infection/10,000 consumers/year. However, both Pyramid and Silverwood lakes are only slightly above the EPA limit. As noted previously, calculated *Cryptosporidium* annual running averages at both Jensen and Mills indicate that oocyst concentrations may generally be below levels requiring additional treatment (Table 12-13). Samples collected under the LT2 ESWTR will help confirm this hypothesis.

Unfortunately, the remaining limitations listed by Anderson could also have a significant impact on the calculated risk assessment. Improved predictions of risk could be achieved through application of risk assessment models specifically developed for each of the reservoirs, rather than extrapolation of results from the Eastside Reservoir study for MWDSC. Therefore, consumer risk assessments at both the 2-log and 3-log removal efficiency levels at these 4 reservoirs should be viewed with caution.

As part of the study by Anderson (2000), daily levels of fecal coliform at Perris Beach and Moreno Beach at Lake Perris were also used in a finite element model developed for Lake Perris. Predicted fecal coliform concentrations were compared with monitoring data collected by the Riverside County Health Department. Anderson found good agreement between the predicted and actual fecal coliform values; however, it would be premature to judge the accuracy of the model based on multiple samples collected at only 1 time of the day. Although encouraging, until samples are collected over the course of the day, the goodness of fit of the model should only be considered preliminary. The model suggested that coliform levels would rise until about 3 PM and then fall throughout the afternoon and evening. At 2 popular swimming beaches on the lake, additional calculations suggested that predicted fecal coliform concentrations might exceed DHS single-sample bathing beaches coliform value of 400 cfu/100 mL a minimum of 2.5% and 5.5% of the time. Fecal coliform levels were not modeled at the remaining 3 reservoirs. Therefore, it is unknown whether the hierarchy of pathogen contamination as recreation use increases would have been similar for bacteria.

Anderson concluded that body-contact recreational activity is predicted to have significant effects on the pathogen concentrations in all of the SWP reservoirs with Lake Perris predicted to experience the most substantial impacts because of its high level of recreational use relative to the volume of its epilimnion. However, Anderson based these conclusions on 2-log removal of *Cryptosporidium*, not the 3-log removal currently assumed for plants meeting IESWTR requirements. If this is the case, then risks fall by a factor of 10. Depending on the levels chosen by the EPA, all lakes might meet the EPA's levels of risk.

Anderson's transport simulations conducted for Lake Perris predicted a complex circulation pattern within the reservoir. Samples collected at Perris Beach at about noon during the summer weekends of 1999 were in good agreement with predicted concentrations using the model. Predicted and observed concentrations near the buoy line were also in good agreement. Using his model, cumulative probability distribution functions developed from coliform monitoring data indicated that fecal coliform concentrations at mid-day would exceed the DHS simple sample limit of 400 cfu/100 mL at a probability of about 2.5% for Perris Beach and 5.5% for Moreno Beach. Because Dr. Anderson's model shows a peak in coliform numbers around 3 PM, this finding suggests that the probabilities for exceeding the recommended DHS single sample limit will be higher later in the afternoon. Additional field samples will be required to verify the model's prediction.

Finally, although *Cryptosporidium* risk may be lower than what is indicated in Dr. Anderson's report, virus removal remains unaffected by new calculations in the LT2 ESWTR. The levels of rotavirus predicted by Dr. Anderson based on the Eastside Reservoir results are high. More detailed modeling using improved rotavirus data would be informative. Nevertheless, if rotavirus or other viruses are perceived as a threat, field monitoring to determine actual concentrations would be advisable.

12.7 PROTOZOAN SAMPLING METHOD CONCERNS

Sampling methodology for *Cryptosporidium* and *Giardia* is still in its infancy. While improvements have been made, problems with the methods often make the interpretation of protozoan results problematic and open to debate. Recommendations made in Chapter 13 for several watersheds have called for more focused studies on pathogen occurrence. Unfortunately, the weaknesses and/or expense associated with the protozoan methods, may compromise the ability to design studies that adequately address the questions requiring study.

The EPA has promulgated 2 methods to determine *Cryptosporidium* and *Giardia* concentrations in source and treated waters. The first, the ICR immunofluorescent assay (IFA) method for pathogens, was proposed in February 1994 but not promulgated until May 1996. One of the reasons for delay involved the scientific issues surrounding the

IFA method used to quantify oocysts (Pontius 1999). In 1998 and 1999, the EPA introduced Method 1622 (for *Cryptosporidium*) and Method 1623 (for *Cryptosporidium* and *Giardia*). DWR's MWQI conducted several studies with either the ICR method or Method 1623.

DWR studies led to the conclusion that the ICR method exhibited poor recovery, accuracy, and precision and that because of these failings, it was impossible to know whether the results accurately reflected pathogen distribution and concentration in source, Delta, SWP aqueduct, and reservoir waters (see Appendix B). These results are not dissimilar from nationwide ICR results. With 18 months of national ICR data analyzed, the majority of samples have found no detection of either *Cryptosporidium* or *Giardia*. Of the 5,829 samples analyzed, 93% have been nondetect for *Cryptosporidium* and 81% have been negative for *Giardia* (Allen and others 2000). Problems with the ICR protozoan method include poor reproducibility, poor sensitivity, high detection limit, high false-positive rate, and high false-negative rate. Allen and others (2000) concluded that since no estimate of the true concentration of pathogens in a sample can be made with confidence, the ICR method should be considered at best a screening test when cysts or oocysts are found, while the lack of organisms does not necessarily mean that the pathogens are not present (Allen and others 2000). Although the EPA has maintained that the collected data from the ICR were adequate for estimating the national occurrence of protozoa, the agency and the water supply profession were concerned that ICR data may not accurately describe protozoa occurrence in drinking water plant source water (Connell and others 2000). This concern led to the Information Collection Rule Supplemental Surveys and the use of Method 1622 and 1623.

While Method 1623 is the best method available to analyze for *Cryptosporidium*, it still has significant problems that compromise the ability to perform studies suggested in this document. Recovery and variability of the method may be influenced by the background matrix of the sample (see also Appendix C). Overlying the issue of method strengths and weaknesses are the inherent problems associated with sampling an organism that is not homogeneously distributed throughout the water column. Regardless of the method, if sampling designs do not account for the spatial variability of organisms, this could lead to false conclusions on concentrations or occurrence. Problems with using Method 1623 for environmental and treated water monitoring have led several researchers to recommend a different approach to assessing pathogen contamination. For water treatment plants, Allen and others (2000) have suggested using source-water protection, treatment optimization, and maintenance of water quality through storage and distribution instead of using monitoring results from Method 1623.

The 3 parameters necessary to ensure statistically valid microbial data are sensitivity, specificity, and reproducibility (coefficient of variation) (Ferraro and Kunz 1982). With respect to these constituents, Method 1623 is an improvement over the ICR method; however, based on these criteria, it still is inadequate to accurately summarize pathogen occurrences. Generally, methods that demonstrate sensitivities and specificities of < 90% and coefficient of variation (CV) of > 15% are too inaccurate and variable to make sound public health decisions (Allen and others 2000). Table 12-18 shows the mean percent recovery and relative standard deviation for *Cryptosporidium* from the EPA's method validation study for Method 1623 in both reagent water and matrix spikes (EPA 1999).

Table 12-18 Final Method 1623 Quality Control Acceptance Criteria

	Mean Percent Recovery	Percent Relative Standard Deviation
Reagent Water Matrix	21% to 100%	40%
Spike/matrix spike duplicate	13% to 111%	61%

Adapted from EPA 1999

Table 12-19 shows the mean percent recovery and relative standard deviation for *Cryptosporidium* for the data collected by the EPA for its supplemental survey sampling program (Connell and others 2000). As shown in Tables 12-18 and 12-19, Method 1623 does not generally meet the accuracy criteria and shows much higher precision than 15%. At this time the true sensitivity of the method is unknown.

Table 12-19 Supplemental Survey Mean Recovery and Relative Standard Deviation

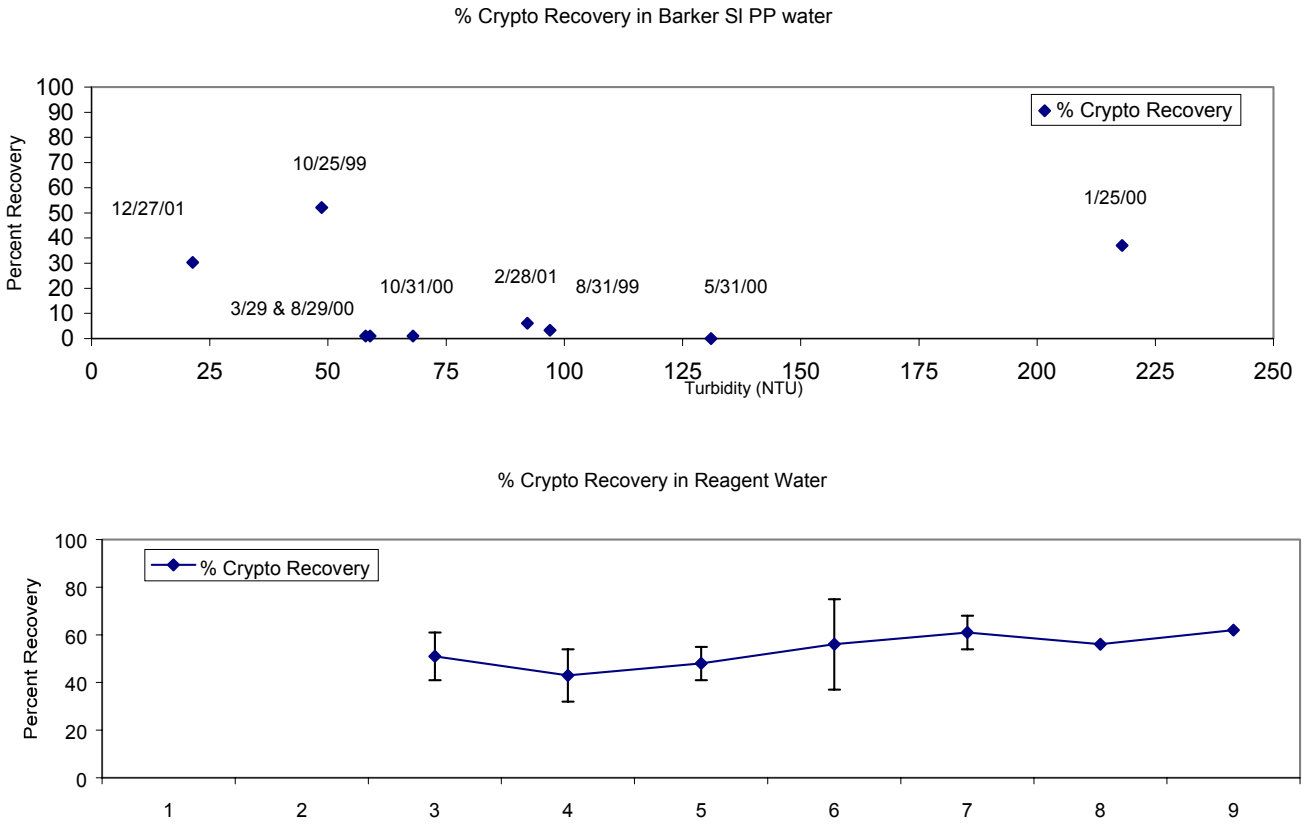
	Mean Recovery	Relative Standard Deviation
Spiked source water	43%	47%

Adapted from Connell and others 2000

Based on the 1623 sampling completed by DWR to date, some of the most acute problems with the method can be observed in the Barker Slough watershed. Increased pathogen monitoring is warranted because of the known presence of livestock in the slough that drains the watershed.

Figure 12-13 shows the results of approximately a year and a half of Method 1623, matrix spike recovery experiments in Barker Slough waters as well as the laboratories' ongoing precision and recovery of spiked samples in reagent water. Average recovery of matrix spikes in Barker Slough water was 15%. The coefficient of variation was 135%. In contrast, the laboratories' average recovery in reagent water was within EPA's criteria for the method with an average recovery of 54% and a coefficient of variation of 13%. In Barker Slough waters, most recoveries ranged between zero and 3%; however, high and low recoveries could be found at high and low turbidities. This suggested that either turbidity was not the variable affecting recovery or that the level of variability with a single sample was so great an extremely large number of replicates would be required to accurately describe the spiking concentration. In either case, the level of accuracy and variability are so poor that accurate counts of *Cryptosporidium* in this water are extremely problematic. As a caveat (shown in Appendix C), the greatest variability associated with MWQI recovery experiments also occurred in Barker Slough water (coefficient of variation of 38%); however, in these experiments, the average percent recovery was 55%. While recoveries were higher, the large variability associated with this recovery result also suggests that a large number of samples would be required to accurately determine oocyst concentrations.

Figure 12-13 Matrix Spike Percent *Cryptosporidium* Recovery in Barker Slough Waters and Ongoing Precision Percent Recovery in Reagent Water



Unlike Barker Slough, coefficients of variation were less than 15% at other sites studied by MWQI (Appendix C). However, while the level of variability was low, recovery may have been influenced by matrix water quality, not turbidity. *Cryptosporidium* recoveries for samples at high and low turbidities were statistically similar; however, recoveries of both high and low turbidity samples differed statistically between the turbidity sample collected between the 2 extremes. This result would not have been expected if turbidity was responsible for method performance.

Before further environmental sampling, 2 experiments should be conducted. The 1st would be to repeat the experiment of Appendix C with more replicates. The 2nd would be to determine if matrix effects are influencing recovery results of the method.

Overlying the issue of method strengths and weaknesses are the inherent problems associated with sampling an organism that is not homogeneously distributed throughout the water column. Based on the total monthly volume of finished water produced and the volume of monthly pathogen samples collected, Allen and others (2000) calculated that of the major utilities they examined, the greatest percentage of total produced water analyzed for protozoans was 0.00039%. In many ways the percentage of source water examined under field conditions is analogous. Unless it is a small stream, the volume of water processed from larger rivers or reservoirs is a small fraction of the total volume of the water body sampled. Since protozoa are not homogeneously distributed in the water body, sampling frequency, location, and volume become critical when trying to characterize organism concentration or origin. Given the method and environmental limitations, the highest chances of success would potentially occur in small, highly polluted streams with data becoming more difficult to interpret with the size and complexity of the water body or watershed.

Given the issues above, environmental sampling of pathogens suggested in this document will be costly to perform, and the data quality may still be questionable even with stringent QA/QC in place. Allen and others (2000) have suggested that pathogen monitoring should be considered only in rare and special instances (for example, research studies, point source evaluations in a watershed, or with an infective outbreak). However, even under these circumstances, the limits of the method must be fully realized. So that the reader can judge the quality of the data for themselves, any results should reflect the specificity, sensitivity, and reproducibility of the method used (Allen and others 2000)

REFERENCES

LITERATURE CITED

Allen MJ, Clancy JL, Rice EW. 2000. "The plain, hard truth about pathogen monitoring." *J Am Water Works Assoc* 92(9):64-76.

Anderson MA. 2000 Aug. *Predicted pathogen concentrations and consumer health risks resulting from body-contact recreation on the East and West Branch State Water Project reservoirs*. Report to the State Water Contractors.

[Anonymous]. 1995. *Standard methods for the examination of water and wastewater.* 19th ed. Washington DC: Prepared and published jointly by American Health Association, American Water Works Association, Water Environment Federation.

Connell K, Rodgers CC, Shank-Givens HL, Scheller J, Pope ML, Miller K. 2000. "Building a better protozoa data set." *J Am Water Works Assoc* 92(10):30-43.

Covert TC, Shadix LC, Rice EW, Haines JR, Freyberg RW. 1989. "Evaluation of the autoanalysis colilert test for detection and enumeration of total coliforms." *Appl Environ Microbiol* 55:2443-7.

[DHS] California Department of Health Services, Office of Drinking Water. 1991 May 15. *Surface water treatment staff guidance manual.* App B.

Edberg SC, Allen MT, Smith DB, and the National Collaborative Study. 1988. "National field evaluation of a defined substrate method for the simultaneous enumeration of total coliforms and *Escherichia coli* from drinking water: comparison with the standard multiple tube fermentation method." *Appl Environ Microbiol* 54:1595-1601.

[EPA] United States Environmental Protection Agency. 1989. *Guidance manual for compliance with the filtration and disinfection requirement for public water systems using surface water sources.* Office of Drinking Water. Contract nr 68-01-6989. Malcom Pirnie and CWC-HDR.

[EPA] United States Environmental Protection Agency. 1999 Apr. *Results of the interlaboratory method validation study for determination of Cryptosporidium and Giardia using US EPA method 1623*. Washington, D.C.: EPA, Office of Water, Office of Science and Technology Engineering and Analysis Division.

[EPA] United States Environmental Protection Agency. 2000 Dec 29. "Stage 2 microbial and disinfection byproducts federal advisory committee agreement in principle." *Federal Register* 65(251).

Ferraro MJ, Kunz LJ. 1982. *Predictive value of microbiologic diagnostic tests. Significance of medical microbiology in the care of patients*. 2nd ed, Lorian V, editor. Baltimore: Williams & Wilkins.

Katamay MM. 1990. "Assessing defined-substrate technology for meeting monitoring requirements of the total coliform rule." *J Am Water Works Assoc* 82(9):83-7.

Pontius FW, Clancy JL. 1999. "ICR Crypto Data: Worthwhile or Worthless." J Am Water Works Assoc 91(9):14-21.

Pope ML, Ellis B, Rosen JS, Connell K, Pulz J, LeChevallier M. 2001. *E. coli microbial index approach for screening source waters for susceptibility to high levels of Cryptosporidium*. ICR Data Analysis Book. Forthcoming.

Smith MM. 1992 Nov. "Comparison of methods for total and fecal coliforms in untreated surface water." Presented at the American Water Works Association, WQTC Toronto, Ontario.

Smith MM. 1999 Nov. "Total coliform methods are *not* equal: sensitivity differences to specific genera of bacteria." Presented at the American Water Works Association, WQTC Tampa, Florida.

Wollin MT, Rhee GY, Hickey P, Wieland M.. 1992. "Comparison of methods for total and fecal coliforms and *Escherichia coli* in drinking water." In: *Technol. Conf. proc*. 1991. Denver, CO: AWWA. p 575-84.

Yates MV, Anderson MA, Gerba CP, Rose JB. 1997. *The impact of body-contract recreation in the Eastside Reservoir Project on 1) pathogen risk to consumers and recreators and 2) MTBE contamination.* Final Report to the Metropolitan Water District of Southern CA. 93 p and apps.

PERSONAL COMMUNICATION

Anderson, Michael, Associate Professor, UC Riverside. 2001. Phone call to Carol DiGiorgio, DWR. Feb. 2

Deol, Gurpal, Laboratory Supervisor, Zone 7. 2001. E-mail to Carol DiGiorgio, DWR. Feb 22.

Haberman, Richard, Supervising Sanitary Engineer, Department of Health Services. 2001. Phone call to Carol DiGiorgio, DWR. Aug 14.

Janik, Jeff, Environmental Specialist IV, Division of Operations and Maintenance, Department of Water Resources. 2001. Phone call to Carol DiGiorgio, DWR. Jan 16.

Mills, Dan, Research Scientist, Department of Health Services. 2001. Phone call to Carol DiGiorgio, DWR. Jan 16.

Pope, Misty, Senior Biologist, DynCorp IET. 2001. Phone call to Carol DiGiorgio, DWR. Jan 16.